MARINE RESOURCE ASSESSMENT FOR THE PUERTO RICO/ST. CROIX OPERATING AREA

FINAL REPORT

NOVEMBER 2002

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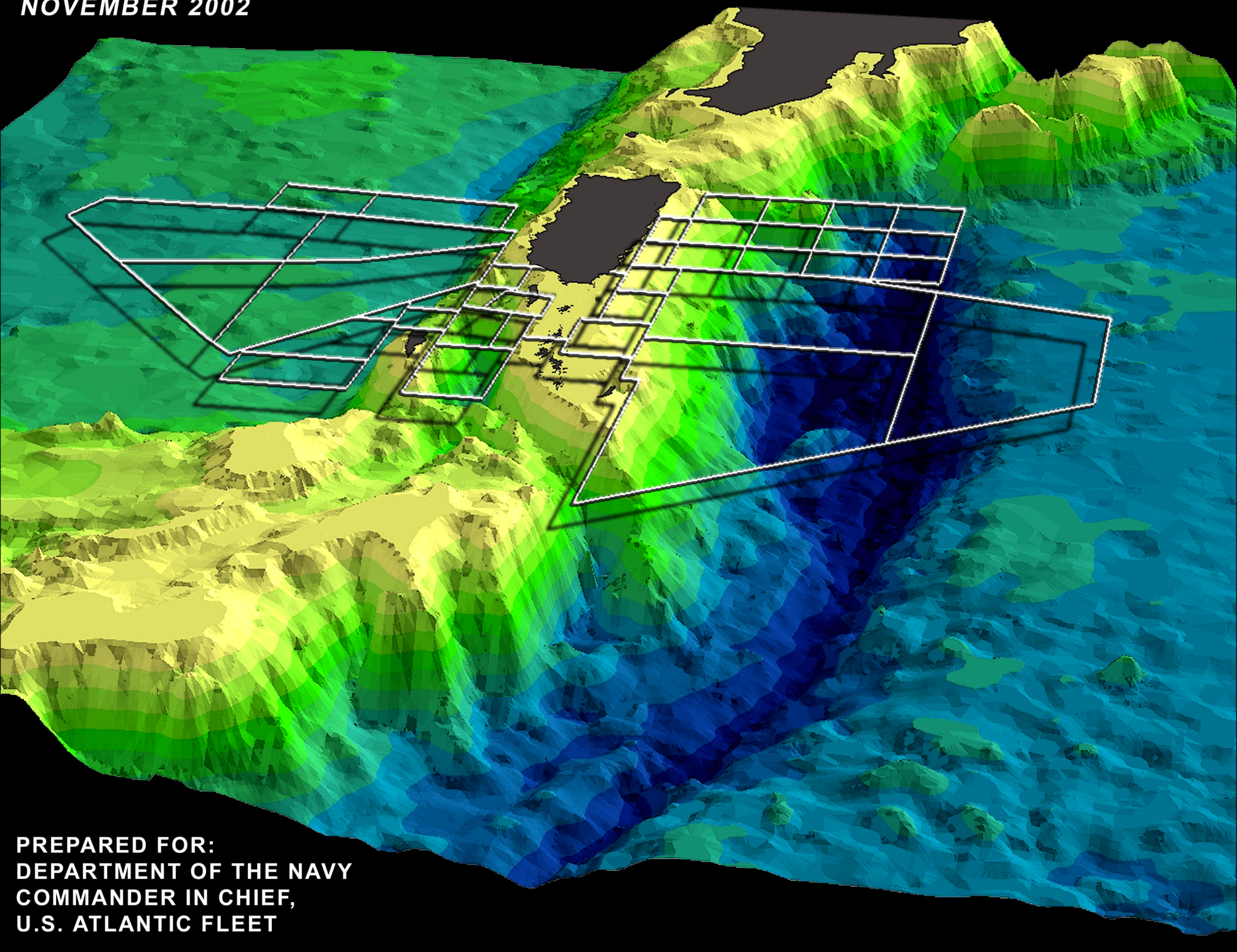

PREPARED FOR:
DEPARTMENT OF THE NAVY
COMMANDER IN CHIEF,
U.S. ATLANTIC FLEET

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Department of the Navy
Commander in Chief,
U.S. Atlantic Fleet

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EXECUTIVE SUMMARY

The Department of the Navy is committed to demonstrating environmental stewardship while executing its national defense mission. The Navy is responsible for compliance with a suite of federal environmental and natural resource laws and regulations that apply to the marine environment, including the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), the Magnuson-Stevens Fishery Conservation and Management Act, and Executive Order 13089 on Coral Reef Protection. The Commander, U.S. Atlantic Fleet (COMLANTFLT) implemented the marine resource assessment (MRA) process to develop a comprehensive compilation of data and literature con-cerning the protected and managed marine resources found in its various operating areas (OP-AREAs). The information in this MRA is vital for planning purposes and for various types of environmental documentation such as biological and environmental assessments that must be prepared in accordance with the NEPA, MMPA, and ESA.

This MRA documents and describes the diversity of marine resources, especially those that are protected or managed, in the North and South Puerto Rico OPAREAs and the St. Croix Underwater Tracking Range (collectively known as the PROA/St. Croix OPAREA). An overview of the marine environment in the PROA/St. Croix OPAREA elucidates the important physical parameters. Detailed information is included on the characteristics and life history of marine mammals and sea turtles that may occur in the PROA/St. Croix OPAREA and vicinity. Seasonal variations in these marine mammal and sea turtle occurrence patterns have been identified, mapped, and described along with the likely causative factors (behavioral, climatic, or oceanographic). The probable distributions of pelagic *Sargassum*, benthic communities including coral reefs, and fishing activities (commercial and recreational) are reviewed as well. Information is provided on such additional considerations as the locations of the U.S. maritime boundaries, navigable waters, marine protected areas, and recreational diving sites in proximity to the PROA/St. Croix OPAREA.

A thorough and systematic search for relevant scientific literature and data was completed. All available sighting, stranding, incidental fisheries bycatch, satellite-tracking, and nesting data for marine mammals and sea turtles were compiled and interpreted to predict the occurrence patterns (concentrated, expected, low/unknown, and not expected) of these protected and managed species. Predictions of the

seasonal occurrence patterns of marine mammals and sea turtles are based on the interpretation of all available data as well as scientific literature and expert opinion.

The geographical representation of the marine resource occurrences in the PROA/St. Croix OPAREA and vicinity was a major constituent of this MRA. A geographic information system (GIS) was used to enter, store, manipulate, and visualize the spatial data and information accumulated for the PROA/St. Croix OPAREA. Over 200 layers of GIS data and information, including bathymetry, sea surface temperature, protected and managed species' occurrences, fishing grounds, Navy OPAREA grids, and maritime boundaries were created. This summary of the marine resources occurring in the PROA/St. Croix OPAREA and vicinity is provided in both paper and electronic form.

REPORT ORGANIZATION

This report consists of nine major chapters and associated appendices:

- **Chapter 1 Introduction**—provides background information on this project, an explanation of its purpose and need, a review of relevant environmental legislation, and a description of the methodology used in the assessment;
- **Chapter 2 Physical Environment**—describes the physical environment of the PROA/St. Croix OPAREA, including the marine geology (physiography, bathymetry, and bottom sediments), physical oceanography (circulation and currents), hydrography (temperature and salinity), and biological oceanography (chlorophyll concentrations and plankton);
- **Chapter 3 Species of Concern**—covers marine mammals and sea turtles found in the PROA/St. Croix OPAREA with detailed narratives of their morphology, status, habitat preferences, distribution, behavior, life history, acoustics, and hearing;
- **Chapter 4 Habitats of Concern**—discusses the occurrence of pelagic *Sargassum*, corals, hard bottom communities, seagrasses, and artificial habitats (artificial reefs and shipwrecks) in the OPAREA and vicinity;
- **Chapter 5 Fish and Fisheries**—investigates fish and fishing activities (commercial/artisanal and recreational) that occur within the OPAREA;
- **Chapter 6 Additional Considerations**—provides information on maritime boundaries, navigable waters/shipping routes, marine protected areas, and recreational diving locations;
- **Chapter 7 Recommendations**—suggests future avenues of research that are necessary to fill the data gaps identified in this project and prioritizes research needs from a cost/benefit approach;
- **Chapter 8 List of Preparers**—lists all individuals that prepared this MRA report;
- **Chapter 9 Glossary**—includes definitions of the terms used in the MRA report;
- **Appendix A**—contains source information for marine mammal and sea turtle data, data confidence levels, and map projection information;
- **Appendix B**—furnishes marine mammal data tables and occurrence maps;
- **Appendix C**—presents sea turtle data tables and occurrence maps; and
- **Appendix D**—provides reference map figures on mylar/transparency sheets.

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LIST OF ACRONYMS AND ABBREVIATIONS

AABW	Antarctic Bottom Water
ACOE	Army Corps of Engineers
BVI	British Virgin Islands
CBW	Caribbean Bottom Water
CD-ROM	Compact Disk-Read Only Memory
CEQ	Council on Environmental Quality
CFMC	Caribbean Fishery Management Council
CFR	Code of Federal Regulations
cm	Centimeter(s)
cm/sec	Centimeters Per Second
COMLANTFLT	Commander, U.S. Atlantic Fleet
CSN	Caribbean Stranding Network
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
dB	Decibel
dB re 1μPa-m	Decibels at the Reference Level of One Micropascal at One Meter Reference Distance
DNER	Department of Natural and Environmental Resources
DoD	Department of Defense
DoN	Department of the Navy
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environment Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESRI	Environmental Systems Research Institute, Inc.
FAD	Fish Aggregating Device
FCMA	Fishery Conservation and Management Act
Fleet	U.S. Navy, Atlantic Fleet
FM	Frequency-modulated
FZ	Fishery Management Zone
FMC	Fishery Management Council
FMP	Fishery Management Plan
FWPCA	Federal Water Pollution Control Act
g C/m^2/yr	Grams of Carbon per Square Meter per Year
GIS	Geographic Information System
HAPC	Habitat Area(s) Of Particular Concern
HSI	Habitat Suitability Index
Hz	Hertz
IUSS	Integrated Undersea Surveillance System
kHz	Kilohertz
km	Kilometer(s)
km^2	Square kilometers
kn	Knot(s)
m	Meter(s)
min	Minute(s)
mm	Millimeter(s)
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MPA	Marine Protected Area
MPPRCA	Marine Plastic Pollution Research and Control Act
MPRSA	Marine Protection, Research, and Sanctuaries Act
MRA	Marine Resource Assessment

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

msec	Millisecond(s)
m/sec	Meters Per Second
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NADW	North Atlantic Deep Water
NARP	National Artificial Reef Plan
Navy	United States Navy
NEPA	National Environmental Policy Act
NERR	National Estuarine Research Reserve
NFEA	National Fishing Enhancement Act
NM	Nautical Mile(s)
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPT	National Parks Trust
NRFCC	National Recreational Fisheries Coordination Council
NSRR	Naval Station Roosevelt Roads
NWR	National Wildlife Refuge
OCS	Outer Continental Shelf
OPAREA	Operating Area
PDF	Portable Document Format
PI	Principal Investigator
PR	Puerto Rico
PROA/St. Croix	North and South Puerto Rico Operating Areas/St. Croix Underwater Tracking Range
psu	Practical Salinity Units
RFRCP	Recreational Fishery Resources Conservation Plan
RMS	Royal Merchant Ship
SAFMC	South Atlantic Fisheries Management Council
S.D.	Standard Deviation
sec	Second(s)
SEFSC	Southeast Fisheries Science Center
SFA	Sustainable Fisheries Act
SAIW	Subantarctic Intermediate Water
TEWG	Turtle Expert Working Group
TIN	Triangular Irregular Network
TIRN	Turtle Island Restoration Network
TTS	Temporary Threshold Shifts
U.K.	United Kingdom
U.N.	United Nations
UNEP	United Nations Environment Programme
URI	University of Rhode Island
U.S.	United States
U.S.C.	United States Code
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USVI	United States Virgin Islands
UTR	Underwater Tracking Range
WIDECAST	Wider Caribbean Sea Turtle Conservation Network
XBT	Expendable Bathythermograph
3D	Three-dimensional
°C	Degrees Celsius
μPa	Micropascal

1.0 INTRODUCTION

This marine resource assessment (MRA) was implemented by the United States (U.S.) Navy's (Navy) Commander, U.S. Atlantic Fleet to initiate collection of data and information concerning the protected and commercial marine resources found in the U.S. Atlantic Fleet's (Fleet) Puerto Rico Operating Areas (OPAREAs) and St. Croix Underwater Tracking Range (UTR). For the purposes of this MRA, the Puerto Rico OPAREAs and St. Croix UTR are considered as one unit or operating area (hereinafter referred to as the PROA/St. Croix OPAREA).

1.1 PURPOSE AND NEED

The goal of this MRA is to describe and document the marine resources in the PROA/St. Croix OPAREA and vicinity, including both protected and commercial marine species. This MRA report provides a compilation of the most recent data and information on the occurrence of these resources in the PROA/St. Croix OPAREA and vicinity. A synopsis of environmental data for the PROA/St. Croix OPAREA and in-depth discussions of the species and habitats of concern found in the eastern Caribbean region are included. The locations of commercial and recreational fishing grounds as well as other areas of interest (such as marine protected areas and scuba diving sites) are also addressed in this assessment.

The assembled information in this MRA will serve as a baseline from which the Navy may evaluate future actions and consider adjustments to training exercises or operations in order to mitigate potential impacts to protected and commercial marine resources. This assessment will contribute to the Fleet's Integrated Long-Range Planning Process and represents an important component in the Fleet's ongoing compliance with U.S. federal mandates that aim to protect and manage resources in the marine environment. All species and habitats that are potentially affected by the Navy's maritime exercises and are protected by U.S. federal resource laws or executive orders are considered in this assessment.

A search and review of relevant literature and data were conducted to summarize the relevant features of the marine environment, the occurrence patterns of protected species, and the distribution of important marine habitats and fishing activities occurring in the PROA/St. Croix OPAREA and vicinity. To describe the physical environment of the PROA/St. Croix OPAREA, physiographic, bathymetric, geologic, hydrographic, and oceanographic data for the eastern Caribbean are presented. All available sighting, stranding, satellite-tracking, and nesting data for marine mammals and sea turtles were compiled and interpreted to predict the occurrence patterns of protected species in the OPAREA. Seasonal variations in occurrence have been identified, mapped, and described along with the associated factors (e.g., behavioral patterns, climate regimes, or oceanographic processes). Characteristics of these species, such as their behavior and life history, relevant to the evaluation of potential impacts of Navy operations are included. The likely distributions of pelagic *Sargassum*, benthic communities (coral reefs, seagrasses, and artificial habitats), and fishing activities (commercial/artisanal and recreational) in the PROA/St. Croix OPAREA and vicinity are also reviewed. Additional considerations, including the locations of U.S. maritime boundaries, commercial shipping lanes, marine protected areas, and recreational diving sites in proximity to the OPAREA, are provided. This summary of the marine resources occurring in the PROA/St. Croix OPAREA and vicinity is provided in both paper and electronic form.

1.2 LOCATION OF STUDY AREA

The PROA/St. Croix OPAREA is located in the northeastern Caribbean Sea and encompasses the waters surrounding three groups of islands: Puerto Rico (PR), the U.S. Virgin Islands (USVI), and the British Virgin Islands (BVI) (Figure 1-1). Within the northern Caribbean region, Puerto Rico completes a chain of several large islands, stretching from west to east, known as the Greater Antilles. This group of islands also includes Cuba, Jamaica, and Hispaniola (Haiti and the Dominican Republic). The U.S. Virgin Islands and British Virgin Islands are part of a chain of much smaller-sized islands known as the Lesser Antilles, which are oriented primarily from north to south at the eastern border of the Caribbean Sea. This island chain terminates near the northern coast of South America. The Lesser Antilles is composed of

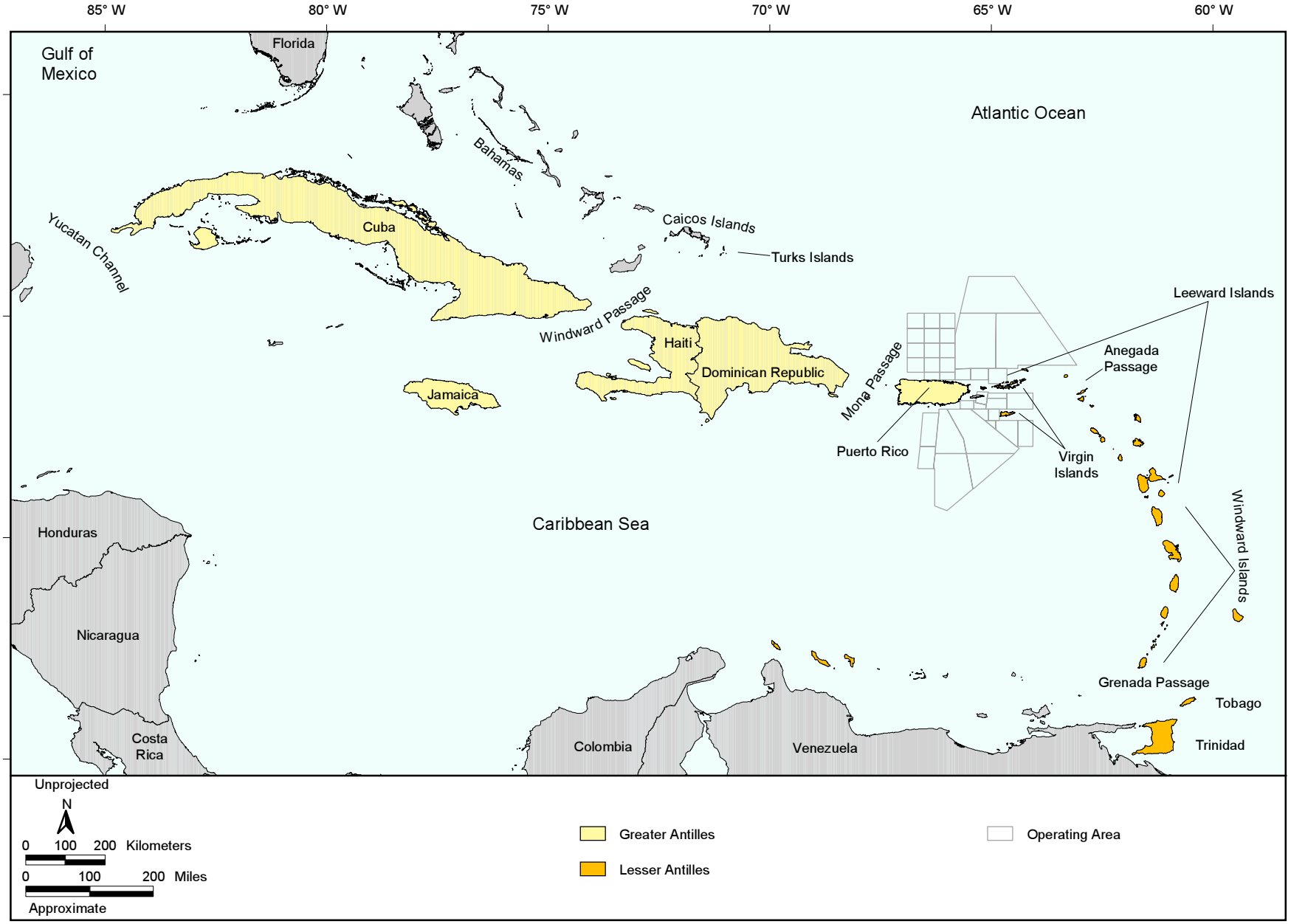

Figure 1-1. The PROA/St. Croix OPAREA is located in the northeastern Caribbean Sea and northwestern Atlantic Ocean. Source data: SRS Technologies. Source maps (scanned): NIMA (1993a, 1993b).

of the Leeward Islands in the north, the Windward Islands in the south, and a few other islands (e.g., Trinidad and Tobago) located off the coast of Venezuela. The Virgin Passage, located between Culebra, PR and St. Thomas, USVI forms the boundary between the Greater and Lesser Antilles (Figure 1-2). Together with the Yucatan Peninsula, the Greater and Lesser Antilles separate the Caribbean Sea from both the Gulf of Mexico and the Atlantic Ocean.

Puerto Rico (a commonwealth) and the U.S. Virgin Islands (a territory) are both possessions of the U.S. while the British Virgin Islands is an overseas territory of the United Kingdom (U.K.). The Commonwealth of Puerto Rico is composed of the large principal island, Puerto Rico, as well as many smaller islands including Mona, Monito, Desecheo, Culebra, Culebrita, Palomino (actually a chain of very small islands), and Vieques (Figure 1-2). Three islands comprise the U.S. Virgin Islands: St. Croix, St. John, and St. Thomas. The British territory, British Virgin Islands, includes many islands, the largest of which are Anegada, Tortola, Jost Van Dyke, and Virgin Gorda.

The PROA/St. Croix OPAREA covers 121,961 square kilometers (km^2) of ocean area. It is composed of the North and South PROAs as well as the St. Croix UTR. However, Warning Area W-371, located in the South PROA adjacent to areas W-374, W-375, and W-376 is not included as part of the OPAREA in this assessment as training operations are not scheduled in this grid block. The North PROA stretches as far north as 20°50'N in the northwestern Atlantic Ocean, while the South PROA extends as far south as 15°33'N in the northeastern Caribbean Sea. The chain of islands running from west to east from Puerto Rico to Sombrero Island separates the two PROAs. The PROA/St. Croix OPAREA reaches as far east as the waters due north of Anguilla and St. Martin at 63°09'W and as far west as the waters off northwestern Puerto Rico at 67°00'W. Important Navy installations in the PROA/St. Croix OPAREA vicinity include Naval Station Roosevelt Roads (NSRR) in eastern Puerto Rico and the Inner Range off eastern Vieques Island.

1.3 APPLICABLE LEGISLATION

The primary environmental laws that govern Navy activities in the marine environment include the National Environmental Policy Act, the Marine Mammal Protection Act, the Endangered Species Act, and the Magnuson-Stevens Fishery Conservation and Management Act. In addition to these acts, there are several other federal mandates and executive orders that deal with resource conservation and management in ocean waters under U.S. jurisdiction. Following is a chronological list of the many laws and regulations that the Navy must consider when conducting maritime operations.

1.3.1 Federal Resource Laws

- The National Environmental Policy Act (NEPA) of 1969 established national policies and goals for the protection of the environment. The NEPA aimed to encourage harmony between people and the environment, to promote efforts to prevent or eliminate damage to the environment and the biosphere, and to enrich the understanding of ecological systems and natural resources important to the country. Thus, environmental factors must be given appropriate consideration in all decisions made by federal agencies.

  The NEPA is divided into two sections: Title I, which outlined a basic national charter for protection of the environment, and Title II, which established the Council on Environmental Quality (CEQ). The CEQ monitors the progress made towards achieving the goals set forth in Section 101 of the NEPA. Other duties of the CEQ include advising the President on environmental issues and providing guidance to other federal agencies on compliance with the NEPA.

  Section 102(2) of the NEPA contained "action-forcing" provisions, ensuring that federal agencies act according to the letter and the spirit of the law. These procedural requirements direct all federal agencies to give appropriate consideration to the environmental effects of their decision-making and to prepare detailed environmental statements on recommendations or reports on proposals for legislation and other major federal actions significantly affecting the quality of the environment.

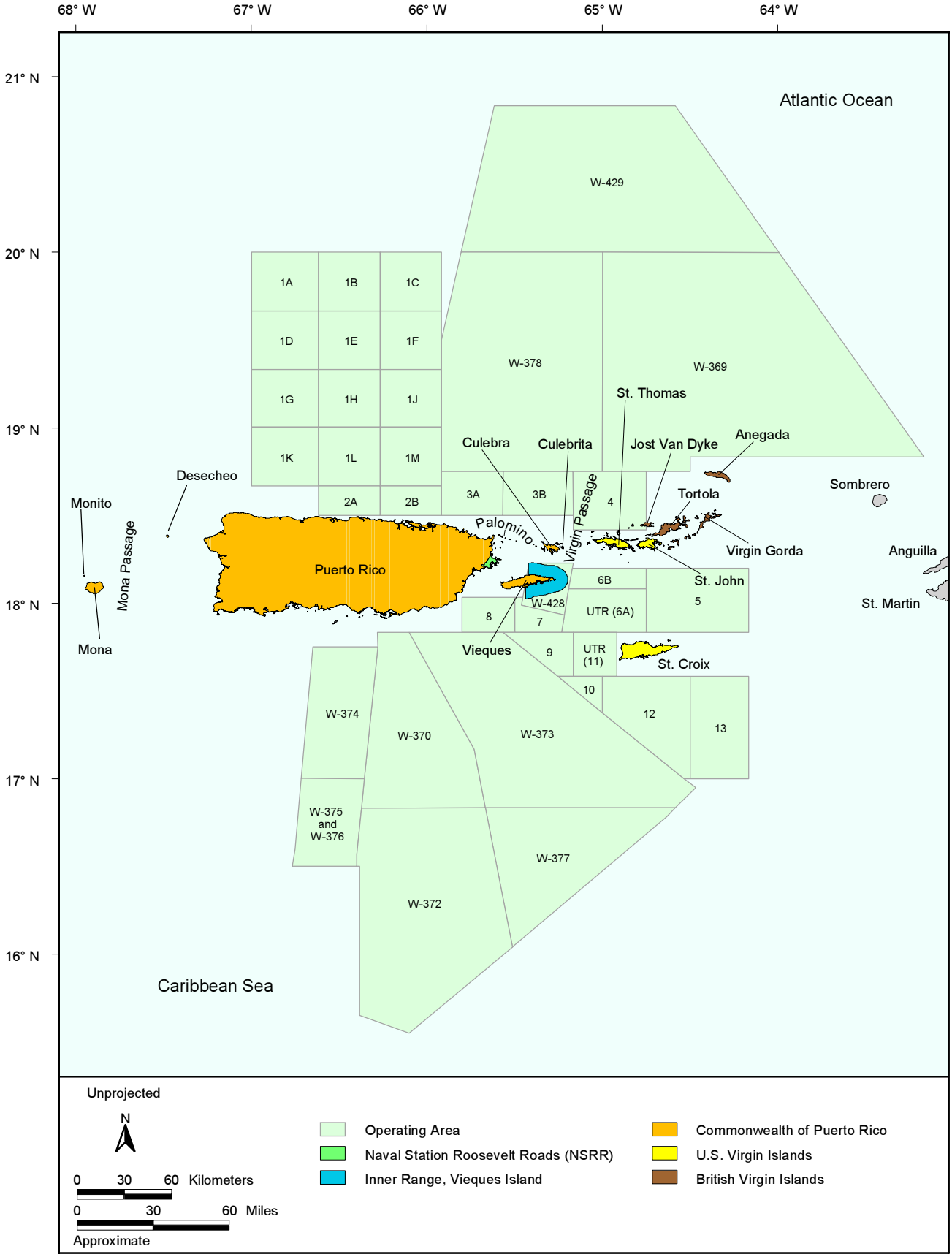

Figure 1-2. The PROA/St. Croix OPAREA consists of the North and South Puerto Rico Operating Areas (PROAs) and the St. Croix Underwater Tracking Range (UTR). The chain of islands running west to east from Puerto Rico to Sombrero separates the North and South PROAs. Source data: Aero-dynamics, Corp. and SRS Technologies. Source maps (scanned): NIMA (1993a, 1993b). Source information: Egan McAllister Associates, Inc. (1999).

Future studies and/or actions requiring federal compliance that may utilize the data contained in this MRA should be prepared in accordance with Section 102(2)(c) of the NEPA, the CEQ regulations on implementing NEPA procedures (40 Code of Federal Regulations [CFR] 1500-1508), and the Department of the Navy (DoN) regulations on implementing NEPA procedures (32 CFR 775).

- The Marine Mammal Protection Act (MMPA) of 1972 established a moratorium on the "taking" of marine mammals in waters or on lands under U.S. jurisdiction. The MMPA defined taking as "harassing, hunting, capturing, killing, or attempting to harass, hunt, capture, or kill any marine mammal" (16 U.S. Code [U.S.C.] 1362[13]). Unless permitted by the Secretary of the Interior or the Secretary of Commerce for use in scientific research or for public display, the importation into the U.S. of any marine mammal parts or products was prohibited. In the 1994 amendments to the MMPA, two levels of "harassment" were defined. Harassment was defined as any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild (Level A), or any act that has the potential to disturb a marine mammal or marine mammal stock in the wild by disrupting behavioral patterns including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (Level B).

  Section 101(a)(5)(A) of the MMPA directed the Secretary of Commerce, upon request, to authorize the unintentional taking of small numbers of marine mammals incidental to activities (other than commercial fishing) when, after notice and opportunity for public comment, the Secretary: (1) determined that total number of takes during a five-year (or less) period have a negligible impact on the affected species or stock, and (2) prescribed necessary regulations that detail methods of taking and monitoring and requirements for reporting. The MMPA provided that the moratorium on takes may be waived when the affected species or population stock is at its optimum sustainable population and will not be disadvantaged by the authorized takes (i.e., be reduced below its maximum net productivity level). Section 101(a)(5)(A) also specified that the Secretary has the right to deny permission to take marine mammals if, after notice and opportunity for public comment, the Secretary finds: (1) that applicable regulations regarding taking, monitoring, and reporting were not followed, or (2) that takes were, or may be, having more than a negligible impact on the affected species or stock.

- The Marine Protection, Research, and Sanctuaries Act (MPRSA), often referred to as the "Ocean Dumping Act," was enacted in 1972, two days after passage of the MMPA. The dumping of waste materials beyond U.S. territorial waters is regulated by the MPRSA; the act also provided guidelines for the designation and regulation of national marine sanctuaries. Persons or vessels subject to U.S. jurisdiction are prohibited by MPRSA Titles I and II from transporting any material out of the U.S. for the purpose of dumping it into ocean waters without a permit. The term "dumping," however, does not include the intentional placement of devices in ocean waters or on the sea bottom when the placement occurs pursuant to an authorized federal or state program. Waste materials include but are not limited to garbage, dredged material, radioactive materials, and construction debris. These materials may be transported to and dumped into the ocean under conditions stipulated by permits issued by the Environmental Protection Agency (EPA) for all waste materials except dredge spoil or by the Army Corps of Engineers (ACOE) for dredged materials. Ocean dumping, however, is possible only if no other reasonable alternatives are available.

- The Coastal Zone Management Act (CZMA) of 1972 established a voluntary national program through which states can develop and implement coastal zone management plans (USFWS 2000). The National Oceanic and Atmospheric Administration (NOAA), under the Secretary of Commerce, administers this act. States use coastal zone management plans "to manage and balance competing uses of and impacts to any coastal use or resource" (NOAA 2000). A coastal zone management plan must be given federal approval before the state can implement the plan (USFWS 2000). The plan must include, among other things, defined boundaries of the coastal zone, identified uses of the area that the state will regulate, a list of mechanisms that will be employed to control the regulated uses, and guidelines for prioritizing the regulated uses. The CZMA also authorized the implementation of a National Estuarine Research Reserve (NERR) system.

In addition, the act provided federal agencies with restrictions concerning their behavior in relation to managed zones. Federal agency actions that affect the zone must be "consistent to the maximum extent practicable" with the applicable plan regulations (Coastal Zone Reauthorization Amendments of 1990). Indirect federal actions, such as activities accomplished with a federal permit, must strictly comply with the applicable plan regulations.

- The Endangered Species Act (ESA) of 1973 established protection over and conservation of threatened and endangered species and the ecosystems upon which they depend. An "endangered" species is a species that is in danger of extinction throughout all or a significant portion of its range while a "threatened" species is one that is likely to become endangered within the foreseeable future throughout all or in a significant portion of its range. All federal agencies are required to implement protection programs for threatened and endangered species and to use their authority to further the purposes of the ESA. The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) jointly administer the ESA and are responsible for the listing (i.e., the labeling of a species as either threatened or endangered) of all candidate species.

  A species may be a candidate for listing as a threatened or endangered species due to any of the following five factors: (1) current/imminent destruction, modification, or curtailment of its habitat or range; (2) overuse for commercial, recreational, scientific, or educational purposes; (3) experiencing high levels of disease or predation; (4) existing regulatory mechanisms offer inadequate protection; or (5) continued existence is being affected by other natural or human-induced factors.

  The major responsibilities of the USFWS and NMFS under the ESA include: (1) the identification of threatened and endangered species; (2) the identification of critical habitats for these species; (3) the implementation of research programs and recovery plans for these species; and (4) the consultation with other federal agencies concerning measures to avoid, minimize, or mitigate the impacts of their activities on these species (Section 7 of the ESA). Further duties of the USFWS and NMFS include regulating "takes" of listed species on public or private land (Section 9) and granting incidental take permits to agencies that may unintentionally "take" listed species during their activities (Section 10a).

  The ESA allowed the designation of geographic areas as critical habitat for threatened or endangered species. Both the physical or biological features essential to the conservation of a threatened or endangered species are included in the habitat designation. Designation of critical habitat affects only federal agency actions and federally funded or permitted activities.

  There are 31 species of marine mammals, six species of sea turtles, and a multitude of marine fish and invertebrate species with potential occurrence in the OPAREA. Seven marine mammal and all six sea turtle species are listed as threatened or endangered (Table 1-1). Of the marine mammal species, the NMFS has jurisdiction over the whales while the USFWS has jurisdiction over the manatee. The NMFS has jurisdiction over sea turtles while they are in the water, and the USFWS has jurisdiction over nesting individuals.

- The Fishery Conservation and Management Act of 1976, later renamed the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), established a 200-nautical mile (NM) fishery conservation zone in U.S. waters as well as a network of regional Fishery Management Councils (FMCs). The FMCs are comprised of federal and state officials, including individuals from the USFWS, the organization that oversees fishing activities within the fishery management zone. The act also established national standards (e.g., optimum yield, scientific information, allocations, efficiency, and costs/benefits) for fishery conservation and management. In 1977, the multifaceted regional management system began allocating harvesting rights, with priority given to domestic enterprises. Since a substantial portion of fishery resources in offshore waters was allocated for foreign harvest, these foreign allocations were eventually reduced as domestic fish harvesting and processing industries expanded under the domestic preference authorized by the MSFCMA. At that time, exclusive federal management authority over U.S. domestic fisheries resources was vested in the NMFS.

Table 1-1. The threatened and endangered marine mammal and sea turtle species with potential occurrence in the PROA/St. Croix OPAREA. Marine mammal taxonomy follows Rice (1998) for the West Indian manatee and IWC (2001) for cetaceans. Sea turtle taxonomy follows Pritchard (1997).

Marine Mammals		
Humpback whale	*Megaptera novaeangliae*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
West Indian manatee	*Trichechus manatus*	Endangered
Sea Turtles		
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Green sea turtle	*Chelonia mydas*	Threatened[a]
Hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Olive ridley sea turtle	*Lepidochelys olivacea*	Threatened[b]

[a] As a species, the green sea turtle is listed as threatened. However, the Florida and Mexican Pacific coast nesting populations are listed as endangered.
[b] As a species, the olive ridley sea turtle is listed as threatened. However, the Mexican Pacific coast nesting population is listed as endangered.

The authority to place observers on commercial fishing and processing vessels operating in specific geographic areas is also provided by the MSFCMA. The data collected by the National Observer Program, which is overseen by the NMFS, is often the best means to get recent data on the status of many fisheries. Without observers and observer programs, there would not be sufficient fisheries data for effective management. Observer programs also satisfy requirements of the ESA and the MMPA by documenting incidental fisheries bycatch of federally protected species, such as marine mammals and sea turtles.

- In 1977, Congress addressed the heightened concern over water pollution by amending the Federal Water Pollution Control Act (FWPCA) of 1948. The 1977 amendments, known as the Clean Water Act (CWA), extensively amended the FWPCA and established the framework for regulating discharges of pollutants into the waters of the U.S. For a synopsis of FWPCA initiatives before 1977, consult USFWS (2000), which documents the history of the FWPCA since its origin.

  Through standards, technical tools, and financial assistance, the CWA was designed to accomplish two goals: (1) to make U.S. waters fishable and swimmable and (2) to eliminate contaminant discharge into U.S. waters. The CWA gave the EPA the authority to implement pollution control programs and continued the provision set in the FWPCA to set water quality standards for all contaminants in surface waters. Section 403 of the CWA established permit guidelines specific to the discharge of contaminants into the territorial sea, the contiguous zone, and waters further offshore (USFWS 2000). Provisions of the CWA required permits for the discharge of pollutants from a point source and funded sewage treatment plant construction (EPA 2002). In addition to regulating pollution in offshore waters, the CWA, under the amendment known as the Water Quality Act of 1987, also required state and federal agencies to devise programs and management plans that aim to maintain the biological and chemical integrity of estuarine waters. In estuaries of national significance, NOAA is permitted to conduct water quality research in order to evaluate state and

federal management efforts. The 1987 amendment phased out the sewage treatment plant funding process and replaced it with a state funded program (EPA 2002).

- In addition to the CWA, the Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987 also regulates the discharge of contaminants into the ocean. Under this federal statute, the discharge of any plastic materials (including synthetic ropes, fishing nets, plastic bags, and biodegradable plastics) into the ocean is prohibited. The discharge of other materials, such as floating dunnage, food waste, paper, rags, glass, metal, and crockery, is also regulated by this act. Ships are permitted to discharge these types of refuse into the water but they may only do so when beyond a set distance from shore, as prescribed by the MPPRCA. An additional component of this act required that all ocean-going, U.S. flag vessels greater than 12.2 meters (m) in length, as well as all manned, fixed, or floating platforms subject to U.S. jurisdiction, keep records of garbage discharges and disposals (NOAA 1998).

- During the reauthorization of the MPRSA in 1992, Title III of the MPRSA was designated the National Marine Sanctuaries Act. Title III authorized the Secretary of Commerce to designate and manage areas of the marine environment with nationally significant aesthetic, ecological, historical, or recreational value as national marine sanctuaries. The primary objective of this law was to protect marine resources, such as coral reefs, sunken historical vessels, or unique habitats while facilitating all compatible public and private uses of these resources. National marine sanctuaries, similar to underwater parks, are managed according to management plans, which are prepared by the NOAA on a site-by-site basis. The NOAA is responsible for administering the National Marine Sanctuary Program.

- In 1996, the MSFCMA was reauthorized and amended by the Sustainable Fisheries Act (SFA). The SFA provided a new habitat conservation tool, the Essential Fish Habitat (EFH) mandate. The EFH mandate required that the regional FMCs, through federal Fishery Management Plans (FMP), describe and identify EFH for each federally managed species, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitats. Congress defined EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” (16 U.S.C. 1802[10]). The term “fish” is defined in the SFA as “finfish, mollusks, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds” (16 U.S.C. 1802[12]). The regulations for implementing EFH clarified that “waters” include all aquatic areas and their biological, chemical, and physical properties, and “substrate” includes the associated biological communities that make these areas suitable fish habitats; the description and identification of the EFH includes habitats used at any time during a species’ life in all its life history stages (NMFS 2002).

  Authority to implement the SFA was given to the Secretary of Commerce through the NMFS. The SFA required that EFH be identified and described for each federally managed species. The identification must include descriptive information on the geographic range of the EFH for all life stages as well as maps of the EFH for life stages, over appropriate temporal and spatial scales. The NMFS and regional FMCs are required to determine the species distributions by life stage and to characterize associated habitats, including habitat areas of particular concern (HAPC). The SFA required federal agencies to consult with the NMFS on activities that may adversely affect EFH. For actions that affect a threatened or endangered species, its critical habitat, and its EFH, federal agencies must integrate ESA and EFH consultations.

  In 2002, the EFH Final Rule was authorized, which simplified EFH regulations (NMFS 2002). Significant changes delineated in the EFH Final Rule are: (1) clearer standards for identifying and describing EFH, including the inclusion of the geographic boundaries and a map of the EFH, as well as guidance for the FMCs to distinguish EFH from other habitats; (2) more guidance for the FMCs on evaluating the impact of fishing activities on EFH and clearer standards for deciding when FMCs should act to minimize the adverse impacts; and (3) clarification and reinforcement of the EFH consultation procedures (NMFS 2002). The process by which federal agencies can integrate MSFCMA EFH consultations with ESA Section 7 consultations is described in NMFS (2002).

1.3.2 Executive Orders

- Executive Order 12114 on Environmental Effects Abroad of Major Federal Actions was passed in 1979 to further environmental objectives consistent with U.S. foreign and national security policies by extending the principles of the NEPA to the international stage. Under Executive Order 12114, federal agencies that engage in major actions that significantly affect a non-U.S. environment must prepare an environmental assessment of the action's effects on that environment. This is similar to an environmental impact statement (EIS) or environmental assessment (EA) developed under the NEPA for environments in the U.S. Certain actions, such as intelligence activities, disaster and emergency relief actions, and actions that occur in the course of an armed conflict, are exempt from this order. Such exemptions do not apply to major federal actions that significantly affect an environment that is not within any nation's jurisdiction, unless permitted by law. The purpose of the order is to force federal agencies to consider the effects their actions have on international environments.

- Executive Order 12962 on Recreational Fisheries was enacted in 1995 to ensure that federal agencies strive to improve the "quantity, function, sustainable productivity, and distribution of U.S. aquatic resources" so that recreational fishing opportunities nationwide can increase. The overarching goal of this order was to promote the conservation, restoration, and enhancement of aquatic systems and fish populations by increasing fishing access, education and outreach, and multi-agency partnerships.

  The National Recreational Fisheries Coordination Council (NRFCC), co-chaired by the Secretaries of the Interior and Commerce, is charged with overseeing federal actions and programs that are mandated by this order. The specific duties of the NRFCC include: (1) ensuring that the social and economic values of healthy aquatic systems, which support recreational fisheries, are fully considered by federal agencies; (2) reducing duplicative and cost-inefficient efforts among federal agencies; and (3) disseminating the latest information and technologies to assist in the conservation and management of recreational fisheries. In June 1996, the NRFCC developed a comprehensive Recreational Fishery Resources Conservation Plan (RFRCP), specifying what member agencies would do to achieve the order's goals (NMFS 1999). In addition to defining federal agency actions, the plan also ensured agency accountability and provided a comprehensive mechanism to evaluate achievements (Panek 1998). A major outcome of the RFRCP has been the increased utilization of artificial reefs to better manage recreational fishing stocks in U.S. waters.

- Executive Order 13089 on Coral Reef Protection was issued in 1998 "to preserve and protect the biodiversity, health, heritage, and social and economic value of U.S. coral reef ecosystems and the marine environment." The executive order directed all federal agencies to protect coral reef ecosystems to the extent feasible and instructed particular agencies to develop coordinated science-based plans to restore damaged reefs as well as mitigate current and future impacts on reefs, both in the U.S. and around the globe (Agardy 2000). This order also established the interagency U.S. Coral Reef Task Force, co-chaired by the Secretary of the Interior and the Secretary of Commerce through the Administrator of the NOAA.

- Executive Order 13158 of 2000 is a furtherance of Executive Order 13089 and was established to create a framework for a national system of marine protected areas (MPAs). An MPA is defined in Executive Order 13158 as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." This executive order strengthened governmental interagency cooperation in protecting the marine environment. The MPA Executive Order also called for stronger management of existing MPAs, the creation of new MPAs, and the prevention of harm to marine ecosystems by federally approved, conducted, or funded activity (Agardy 2000).

1.4 METHODOLOGY

1.4.1 Literature and Data Search

A thorough and systematic search for relevant scientific literature and data was conducted. Once identified, information vital to the production of this MRA report was obtained, reviewed, and catalogued. Of the available scientific literature (both published and unpublished), the following types of documents were utilized in the assessment: journals, periodicals, bulletins, monographs of scientific and professional societies, theses, dissertations, project reports, endangered species recovery plans, stock assessment reports, EISs, FMPs, and other technical reports published by government agencies, private businesses, or environmental consulting firms. Scientific literature was also consulted for marine resource occurrence information, especially geographic coordinates, within the PROA/St. Croix OPAREA.

Information from the following sources was collected to investigate the physical environment; to determine the occurrence of marine mammals, sea turtles, pelagic *Sargassum*, benthic habitats, recreational and commercial fishing grounds; and to ascertain the distribution of shipping routes, maritime boundaries, diving sites, and MPAs in the waters of the PROA/St. Croix OPAREA:

- Academic and educational/research institutions (Caribbean Conservation Corporation, Caribbean Stranding Network [CSN], College of William and Mary, Duke University, Florida Marine Research Institute, Old Dominion University, Puerto Rico Sea Grant, Texas A&M University, Texas A&M University at Galveston, University of Miami, University of North Texas, University of Puerto Rico at Mayaguez, University of Rhode Island, University of Texas at Dallas, and Virginia Institute of Marine Science);

- University on-line databases: DIALOG (Oceanic Abstracts, Enviroline, Pollution Abstracts, Aquatic Sciences and Fisheries Abstracts, Life Science Collection, Zoological Record Online, Water Resources Abstracts, National Technical Information Service, Federal Register, Dissertation Abstracts, and BIOSIS Previews), First Search (BIODigest, BiolAgrindex, GenSciIndex, and the Government Printing Office), and Cambridge Abstracts;

- The Internet, including various databases and related websites (NOAA, NMFS, U.S. Geological Survey [USGS], Caribbean Fishery Management Council [CFMC], South Atlantic Fishery Management Council [SAFMC], Naval Oceanographic Office, Department of State, Central Intelligence Agency, United Nations Environment Programme [UNEP], Caribbean Environment Programme, Natural Resources Defense Council, The Nature Conservancy, Elsevier, Allen Press, Blackwell-Science, ReefBase, Reef Environment Education Foundation, Food and Agriculture Organization, Federal Register, Marine Turtle Newsletter, Proceedings of the Annual Sea Turtle Symposium, University of Florida Sea Turtle Bibliography, Billfish Tournament Network, International Game Fish Association, and the National Sea Grant Library);

- International organizations (UNEP: Caribbean Environment Programme, World Conservation Monitoring Centre; Wider Caribbean Sea Turtle Conservation Network); territorial agencies (Puerto Rico Department of Natural and Environmental Resources [DNER], British Virgin Islands National Parks Trust, U.S. Virgin Islands Department of Planning and Natural Resources); and federal agencies (USGS; NOAA [NMFS: Office of Protected Resources, Office of Habitat Protection, Southeast Fisheries Science Center; National Ocean Service; National Marine Mammal Laboratory; CFMC; SAFMC]; USFWS [Ecological Services Field Offices; National Wildlife Refuge System]; U.S. National Park Service [Buck Island Reef National Monument; Virgin Islands National Park]; National Aeronautic and Space Administration; Marine Mammal Commission; Minerals Management Service; and U.S. Coast Guard); and

- Marine resource experts/specialists.

1.4.2 Spatial Data Representation—Geographic Information System

The geographical representation of marine resource occurrences in the PROA/St. Croix OPAREA and vicinity was a major constituent of this MRA report. The marine resources data and information accumulated for this project were accessed from a wide variety of sources, were in disparate formats, covered a broad range of time periods, and represented differing levels of accuracy as well as quality assurance. The spatial or geographical component that was common to all datasets allowed the widely dissimilar data to be visualized in a meaningful manner. Without this common data characteristic, graphical display of such disparate data would have been difficult, if not impossible, to achieve.

A geographic information system (GIS) was used to store, manipulate, analyze, and visualize the spatial data and information accumulated for the PROA/St. Croix OPAREA. For this project, Environmental Systems Research Institute, Inc.'s (ESRI) ArcView® version 3.2 GIS software was used to create the majority of map figures and ArcView® version 8.2 was used to create the metadata as well as some features of the three-dimensional map figures. ArcView® was chosen for this project due to its widespread use, ease of operation, and its ability to create multiple views and layouts within the same project file.

The geographic locations of important marine resources in the PROA/St. Croix OPAREA and vicinity were derived from four types of data or information sources (in order of reliability): source data, scanned source maps, source information, and information adapted from published maps. “Source data” include geographic coordinates and GIS shapefiles. Some of the data were only available as graphical representations or “source maps.” These data were electronically scanned, imported into ArcView®, and geo-referenced using the Image Analysis extension with significant information being digitized into a shapefile format. Materials acquired as Adobe® Portable Document Format (PDF) files were also treated as scanned source maps (i.e., they were geo-referenced and pertinent information was digitized) since they were already in a digital form. A third type of source, “source information,” encompassed information that was neither taken from a scanned map nor was available in coordinate form. For example, maps displaying non-coordinate data, information given via personal communication, or information extracted from a literature description are referenced as source information. Spatial representations of this type of information were created and geo-referenced. In certain cases, source maps and/or information had to be interpreted to be usable in the GIS environment. Maps displaying geographic information that was interpreted or altered from the original source map/information are noted in the figure caption as being “adapted from” that source.

The source type and associated references for all marine resource data presented in the map figures are listed in each figure’s caption. The full reference citations for map source data or information may be found in the Literature Cited section of each MRA chapter. The two primary types of spatial information used in the PROA/St. Croix OPAREA MRA were coordinate data and scanned maps. These two source types are associated with differing levels data reliability or confidence (see Appendix A, Table A-1 for a further explanation of data confidence). Numerical or authentic data are associated with the highest level of reliability while data obtained by scanning source maps is less reliable.

Problems were encountered when datasets were combined during the development of the map figures. Source data were not in a standard format, there was no standard naming convention for species names, and some datasets included missing or unlabeled data fields. To mitigate these difficulties, many steps were taken to standardize and ensure the quality of the numerical data, especially for the marine mammal and sea turtle data. Therefore, prior to using the data, a master database was created in Microsoft® Access where the data format was standardized so that the data could be merged and later used in the GIS. To accomplish this, data were manipulated to match dataset records with a set of standard field names. In some cases, the latitude and longitude had to be converted to decimal-degrees with accuracy to the fourth decimal place. Species’ common names were added to the database to replace the multiple species codes that accompanied the original data. The different types of codes used for species names in the original datasets were not always consistent from one dataset to the next. To maintain the integrity of the original data, all fields and records were kept without alteration. When

necessary, fields were created to add supplemental information or data that was altered from that given in the original data source. Fields that were added are signified by the “GMI_” prefix. For example, source fields were added to the main dataset to indicate the origin of the data and are shown in the field as “GMI_source.”

GIS data are displayed as layers or "themes" for which scale, areal extent, and display characteristics can be specified. Multiple themes are represented on an individual map figure. Throughout the assessment process, data imported into ArcView® had to be maintained in the most universal, least transformed manner in order to avoid conflict between theme coordinate systems and projections. In the GIS, the most flexible spatial data format is the unprojected geographic coordinate system, which uses decimal-degree latitude and longitude coordinates (see Appendix A-1 for more information on map projections). The decimal-degree format is the only coordinate system format that allows unlimited, temporary, custom projection and re-projection in ArcView® and is therefore the least restrictive spatial data format. The printed maps and electronic GIS map data for this MRA report are unprojected and are therefore not as spatially precise (in terms of distance, area, and shape) as a projected map. Consequently, the map figures should not be used for measurement or analysis.

Once the marine resource data were imported and stored in the GIS, maps were created representing multiple layers of either individual or combined data. The majority of maps in this report are presented in two forms: a display that includes four seasonal maps per page and a display that includes one full-page map. Maps of each display type are presented at the same approximate scale; the full-page maps are at the approximate scale of 1:3,500,000 while each of the seasonal maps (one of four maps per page) is shown at the approximate scale of 1:7,000,000. The maps in this MRA report are presented in kilometers and statute miles; nautical miles currently cannot be displayed for a scale bar in ArcView® 3.2.

The ability to display and analyze multiple data themes or layers simultaneously is one of the advantages to using a GIS rather than other graphic software. Customizations were made to the software in Avenue®, ESRI's proprietary macro-language, to automate the more repetitive map-making tasks as well as the processing and analysis of large volumes of data.

1.4.2.1 Maps of the Physical Environment—Oceanography

While many of the map figures in this chapter utilized data that were acquired from published literature that had been scanned or from electronic map figures, bathymetric data were acquired as geographic coordinates (source data) giving depth below mean sea level. Data points were distributed in 2-minute (min) intervals across the PROA/St. Croix OPAREA vicinity. These point data were imported into the Spatial Analyst extension of ArcView® software, which interpolated and contoured the data at 10 m intervals. Selected isobaths from the resulting two-dimensional contours are shown on various maps throughout the MRA report. The continental shelf break displayed on nearly all map figures included in this MRA was created using GIS in conjunction with the definition for the gradient change that occurs at the shelf break. This “true” shelf break was created using the 2-min contoured bathymetry data as the main geographic reference and therefore reflects the level of precision and accuracy of that data. The line depicting the continental shelf break does not follow a single isobath but varies in water depth, ranging from 1 to 100 m.

Bathymetry for the ocean floor underlying the PROA/St. Croix OPAREA and its vicinity, including the Puerto Rico Trench, are illustrated three-dimensionally. Triangular irregular networks (TINs), which interpolate intermediate data values between original data points, were created from the bathymetry data using the ArcView® 3D Analyst extension. To show the three-dimensional (3D) bathymetry of the OPAREA, TINs were created directly from the 2-min point data; to depict the 3D bathymetry of the Puerto Rico Trench, TINs were instead created from data contoured at 100 m intervals. The TINs were added to the ArcView® 8.2 ArcScene® extension to achieve the full 3D display. ArcScene® allows the 3D display to be manipulated (rotated and tilted). The most authentic display was exported directly from an ArcScene® view as a graphic file (.tif), which was then imported into ArcView® for the final map layout.

1.4.2.2 Biological Resource Maps—Species of Concern

Marine mammal and sea turtle occurrence data were accumulated from every available source; however, it was impossible to obtain every data source in existence for the PROA/St. Croix OPAREA (Appendix A-2). All available marine mammal and sea turtle aerial and shipboard sighting survey, opportunistic sighting, stranding, incidental fisheries bycatch, radio- or satellite-tagging, and nesting/track data were compiled and used in this MRA (Appendix A, Table A-2). The shipboard data were obtained from NMFS-SEFSC while the aerial survey data came from a variety of sources. Data coverage is greatest in the areas closest to the Puerto Rico Platform in the OPAREA (Figure A-1).

In addition to data taken from agencies and institutions, miscellaneous sighting data available from the scientific literature were also used in this MRA. These data were vital to predicting seasonal occurrence patterns for protected species known to inhabit the waters of the PROA/St. Croix OPAREA. Seasons throughout the report are defined as winter (January through March), spring (April through June), summer (July through September), and fall (October through December).

When working with the marine mammal and sea turtle data, several assumptions were made. First, it was assumed that the species identifications given in the original datasets were correct. This assumption was necessary since the reliability of species identifications from one dataset to the next was not always known. For the sake of consistency, reliability of species identifications was not considered in the plotting of any marine mammal or sea turtle data.

Although it was assumed that the species identifications were correct, it could not always be assumed that the geographic coordinates given in the dataset were correct. Problems were often encountered when the original data coordinates were plotted and animals were shown to occur in unexpected locations. This was especially true of the stranding data. For example, the geographic coordinates of several strandings indicated that they occurred well out to sea or far inland. In such cases, the stranding record was verified for accuracy and then moved as close to the original geographic description as possible. If a stranding record could not be verified as accurate and was too far offshore or inland to estimate a likely shore position, it was deleted.

An underlying premise used during the map creation process was that a conservative approach to delineating occurrence patterns of marine mammals and sea turtles was necessary since all six sea turtles and several of the marine mammals are either endangered or threatened. This approach included, whenever possible or pertinent, the use of sighting data from a broader taxonomic level. For example, in considering the distribution of fin whales, we also considered the distribution of unidentified rorquals, the family to which fin whales belong. This provided additional information to aid in the determination of the possible occurrence patterns of this species.

In order to effectively work with the marine mammal data and determine the possible effect of unidentified cetaceans on the distribution of the other cetacean species, it became necessary to combine certain groups of unidentified animals. There were many categories of unidentified cetacean species, as the species identifications were not standard. Examples are unidentified small whales, unidentified large whales, unidentified rorquals, and unidentified dolphins. For the purposes of this project, most categories of unidentified species were merged to create one category called unidentified cetaceans. There were some exceptions to this combining process. Unidentified rorquals (the family of baleen whales which includes the blue, fin, sei, minke, Bryde's, and humpback whales) were left as a separate group to conservatively determine endangered whale distribution for the PROA/St. Croix OPAREA. Although the category of unidentified rorquals includes the non-endangered/non-threatened minke and Bryde's whales, it seemed appropriate to use the group of unidentified whales when determining the distribution of endangered whales in the PROA/St. Croix OPAREA, as most rorquals are endangered species.

The data for individual and groups of species were used to develop polygons of seasonal occurrence for marine mammal and sea turtle species. Four types of occurrence information may be displayed on each turtle or mammal map: areas of "expected occurrence" (areas encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and the available sighting,

stranding, and, when applicable, nesting or tagging data), areas of "concentrated occurrence" (subareas of a species' expected occurrence where there is the highest likelihood of encountering that species; this designation is based primarily on areas of concentrated sightings and preferred habitat), areas of "low/unknown occurrence" (areas where a species is believed to be rare or the likelihood of encountering that species is not known), and areas labeled "occurrence not expected" (areas where a species is not expected to be encountered).

A high number of sightings indicates nothing about the number of individual animals associated with each sighting; a sighting for some species, particularly some dolphin species, may involve a very large group, consisting of hundreds, even thousands of individual animals. The degree of detailed information regarding group size varied widely across datasets.

1.4.2.3 Biological Resource Maps—Habitats of Concern

Multiple sources of data and information were used in the creation of maps for the habitats of concern. Since current information on the occurrence of pelagic *Sargassum* in the North Atlantic Ocean and the Caribbean Sea is not available, several historical maps of this macroalgae's distribution (dating back to 1891) were scanned from the scientific literature to create the composite map of pelagic *Sargassum*. The maps displaying benthic communities are also good examples of multiple data sources being used in the creation of a single map. These maps were created using source data (GIS shapefiles and coordinate data) as well as scanned images that were available from the scientific literature and governmental agencies.

1.4.2.4 Biological Resource Maps—Fish and Fisheries

The commercial/artisanal and recreational fishing maps are also composites of multiple data sources. Most of these maps were created from habitat descriptions provided in fish stock assessments and other similar technical reports. Since the information used to determine a fishing ground's location was often not available in a format compatible with GIS (i.e., was not available as a scannable map or geographic coordinates), the displayed fishing grounds were instead based upon an important limiting parameter (e.g., bathymetry, distance from shore), which was described in the source document as restricting the fishery geographically. Cases in which fishing grounds were created solely from habitat descriptions are noted in the figure caption with the term "Map adapted from" preceding the source.

To display the likely extent of recreational fishing tournaments by season, a 360° buffer (radius 75 NM) was created around each city or island's perimeter where a tournament is known to originate. Due to long travel times from shore, it was assumed that fishermen would probably not journey more than 75 NM offshore during the course of any offshore tournament. To show this information graphically, the 360° buffers were clipped to the shoreline to show the projected area of ocean coverage for each tournament.

1.4.2.5 Maps of Additional Considerations

Information regarding U.S. maritime boundaries, navigable waters, MPAs, and recreational diving sites in the PROA/St. Croix OPAREA and vicinity was gathered from a wide array of sources. Maps displaying the locations of the U.S. exclusive economic zone (EEZ) and major commercial shipping lanes around Puerto Rico and the U.S. Virgin Islands were created from data, maps, and information available in U.S. government agency documents and websites. MPAs and recreational diving sites were depicted using geographic data and information that were either donated by on-site specialists or available from the primary, secondary, and tertiary literature. The creation of the U.S. territorial waters was accomplished by buffering 12 NM outward from the shoreline of all the Puerto Rican islands as well as the islands in the USVI. The coastline of each island was splined to reduce the number of vertices and expedite the buffering process. The areas where the 12 NM buffers overlapped between islands were merged to create the smoothed and continuous territorial waters data layer.

1.4.3 Inherent Problems with Marine Survey Data

When attempting to use aerial and shipboard survey data as a major indicator of a species' occurrence, it is necessary to first recognize the inherent problems associated with each survey type. One of the main drawbacks of surveys in the marine environment is that shipboard and aerial surveys count the number of animals at the water's surface, where species such as cetaceans and sea turtles spend relatively little time. Since sea turtles spend over 90% of their time underwater, it has been estimated that marine surveys undersample (underestimate) the total number of sea turtles in a given area by as much as an order of magnitude (Shoop and Kenney 1992; Renaud and Carpenter 1994). While scientists have devised mathematical formulas to account for animals not seen at the surface, the diving behavior of one individual may be different from that of other members of the same species. Even though marine mammals and sea turtles are obligated to come to the surface to breathe, many individuals will not surface within an observer's field of view. This is of particular concern when attempting to sight species that dive for extended periods of time, do not possess a dorsal fin, and are known to exhibit cryptic behavior, such as beaked whales, *Kogia* spp., and sperm whales (Würsig et al. 1998; Barlow 1999). Beaked whales are often solitary individuals, which makes their sightability much different from a species that regularly occurs in large groups, such as dolphins in the genus *Stenella* (Scott and Gilbert 1982).

Sighting conditions also affect the sightability of marine mammals and sea turtles. Sighting frequencies vary due to the amount of sun glare on the water's surface, the sea state, and the water clarity. Both sea state and glare have statistically significant effects on sighting frequency (Scott and Gilbert 1982; Thompson 1984). When water clarity is poor, animals are difficult to sight below the water's surface, and only those animals at the water's surface that are extremely close to the observer are usually identifiable.

Problems also arise when attempting to select an optimal and efficient survey method for sampling marine mammals and sea turtles. Since most surveys are multi-species surveys, the sampling design, although likely cost- and labor-efficient, cannot be considered optimal for each species (Scott and Gilbert 1982). The altitude at which marine mammal aerial surveys are flown is much higher than is desirable to sight sea turtles (which are typically much smaller than cetaceans). Shipboard surveys designed for sighting marine mammals are adequate for detecting large sea turtles but usually not the smaller-sized turtles. Their relatively small size, diving behavior, and startle responses to vessels and aircraft make smaller sea turtles difficult to sight or visually observe from a ship. The youngest age-classes, which often inhabit waters far from land, are extremely difficult to spot. There have been no shipboard surveys in the Atlantic Ocean, Gulf of Mexico, or Caribbean Sea designed to specifically address information needs relative to sea turtles. Other difficulties with marine surveys include weather, time, and logistical constraints. For example, the operating cost for a research vessel is approximately $10,000 per day (Forney 2002).

In addition, marine surveys are unable to assist scientists in accurately describing the seasonal occurrence of marine mammals and sea turtles in extremely large areas such as the Atlantic Ocean and Caribbean Sea. The occurrence of marine mammals and sea turtles in an area often changes on a seasonal basis in response to changes in water temperature, the movement and availability of prey, or an individual's life history requirements, such as reproduction. Therefore, the number of sightings on a specific date over a specific trackline may not be representative of the number of individuals occurring in the entire area over the course of an entire season. As a result, sighting frequency is often a direct result of the level of survey effort expended in a given area.

1.4.4 Inherent Problems with Stranding Data

Data on marine mammal and sea turtle strandings were used as supplemental information in predicting occurrence patterns of these protected species in the PROA/St. Croix OPAREA, since the majority of the data collected for this project came from a stranding database provided by Dr. Antonio Mignucci-Giannoni of the CSN. In the case of sea turtles, nearly all occurrence records for the U.S. Virgin Islands and British Virgin Islands came from the CSN stranding dataset. Aerial and shipboard surveys are most successful in determining occurrence patterns of marine mammals and sea turtles when the sighting conditions are optimal. Stranding networks, however, often operate year-round, even in inclement

weather. Stranding records, therefore, can be a useful tool when used to supplement sighting survey data for seasons in which there is little to no survey effort.

How closely the distribution of marine mammal and sea turtle stranding records mirrors the actual occurrence of a species in a given region is often not known. Sick animals may strand well beyond their normal range and carcasses may travel long distances before being noticed by observers. Stranding frequency in a given area is as much a function of nearshore and offshore current regimes and coastal zone patrol efforts as it is a function of the stranded species' actual pattern of occurrence. Since coastal species will strand more frequently than oceanic species due to their closer proximity to shore, stranding frequencies should not be used when attempting to compare the occurrence of a coastal versus an oceanic stock in a certain area. Comparisons can not be made between species of differing sizes and social structures, as strandings of large-bodied species and groups of individuals are much more likely to be reported than strandings of small-bodied species or single individuals. An additional problem with the use of stranding data involves the inability of reporters to identify carcasses as a certain species. For example, only the most experienced marine mammal scientists are likely able to differentiate between the several species of beaked whale in the genus *Mesoplodon*.

1.5 REPORT ORGANIZATION

This report consists of nine major chapters and associated appendices. The Executive Summary provides an overview of the important aspects of this MRA report. Chapter 1—Introduction provides background information on this assessment project, an explanation of its purpose and need, a review of relevant environmental legislation, and a description of the methodology used in the preparation of the assessment. Chapter 2—Physical Environment describes the physical environment of the PROA/St. Croix OPAREA, including the physiography, bathymetry, circulation/currents, hydrography (surface temperature and salinity), as well as plankton and primary productivity relevant to this area. Chapter 3—Species of Concern covers two protected taxa found in the PROA/St. Croix OPAREA: marine mammals and sea turtles. For these species, detailed narratives of their morphology, status, habitat preferences, distribution, behavior, life history, acoustics, and hearing have been provided. Chapter 4—Habitats of Concern discusses the occurrence of pelagic *Sargassum*, coral reefs, seagrasses, and artificial habitats (including artificial reefs, shipwrecks, and fish aggregating devices) in the OPAREA and vicinity. Chapter 5—Fish and Fisheries investigates both fish and fishing activities (commercial/artisanal and recreational) that occur within the OPAREA. Chapter 6—Additional Considerations provides information on U.S. maritime boundaries, navigable waters, MPAs, and recreational diving locations. Chapter 7—Recommendations suggests future avenues of research that may fill the data gaps identified in this project and prioritizes research needs from a cost-benefit approach. Chapters 8 and 9 are the List of Preparers and Glossary, respectively. Appendix A includes supplementary materials referred to in the Introduction (including the marine mammal and sea turtle data sources) while Appendices B and C contain data tables and occurrence map figures that are described or referenced in the marine mammal and sea turtle sections (3.1 and 3.2, respectively) of Chapter 3. Appendix D includes six map figures produced on mylar or transparency sheets. These map figures are included as helpful references and can be overlain on any of the map figures within this MRA report.

This report is written in a format and reference style similar to that found in *The Chicago Manual of Style*, 14th Edition. Cited literature appears at the end of each chapter except in Chapter 3, Species of Concern, where it appears at the end of each chapter section.

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2.0 PHYSICAL ENVIRONMENT OF THE PROA/ST. CROIX OPAREA

The Caribbean Sea is a relatively small, nearly enclosed, tropical sea that is separated from the North Atlantic Ocean on the north and east sides by the complex island archipelago chain of the Antilles Island Arc (Greater and Lesser Antilles islands) and to the west and south by the land masses of Central and South America, respectively (Figure 2-1). The PROA/St. Croix OPAREA encompasses the ocean area where the northwestern Atlantic Ocean and northeastern Caribbean Sea meet at the intersection of the Greater and Lesser Antilles island chains. The closely spaced islands of the Antilles Arc form nine passages that funnel the inflowing Atlantic Ocean waters into the Caribbean Sea.

The Caribbean Sea is generally considered to be oligotrophic (37-55 g $C/m^2/yr$) but is seasonally influenced by the enormous freshwater and nutrient input from the Amazon and Orinoco Rivers (equal to 20% of the world's annual river discharge) (Müller-Karger et al. 1989). The climate in the Caribbean region is tropical, with warm temperatures (about 31°C, maximum mean temperature) and seasonally varying rainfall. In the PROA/St. Croix OPAREA vicinity, the rainfall annually ranges from <12 cm near the coast to >500 cm in the mountain island interiors (Beach 1975). Rainfall on the islands of the eastern Caribbean Sea is so variable that geographic areas separated by as little as 20 km experience as much as a five-fold difference in the amount of rain that falls (FAO 1993). Tropical storms and hurricanes occur primarily during late summer and early fall while winds are generally strongest in spring and summer. Winds along the south coasts of Puerto Rico are modified by land and flow from the southwest (FAO 1993). Weather in the Caribbean is determined by the interaction of the easterly flowing Trade Winds, the mid-latitude high-pressure cell found in the North Atlantic Ocean, and cold fronts arriving from the north and northwest.

The islands of the Greater Antilles, particularly Puerto Rico and the Virgin Islands, are exposed on their unprotected northern shores to the higher wave energy of the open Atlantic Ocean. Large swells, with 12 to 16 sec periods and heights to 4 m, are common during November through April on the northern shores of these islands (Morelock et al. 2000). These large swells usually accompany frontal systems arriving from the north. Dangerous waves also develop in the narrow channels and passages between islands due to the concentration of the wave's energy by the bottom topography.

Biologically, the Caribbean Sea is similar to other tropical regions of the world. The predominant shallow water and coastal marine habitats include mangrove forests, seagrass beds, and coral reefs. Fish diversity is high, particularly of coral reef and deepwater fish species. Marine mammals, sea turtles, and marine birds are plentiful in the Caribbean Sea, especially in the protected and productive coastal environments.

2.1 MARINE GEOLOGY

2.1.1 Geologic Setting of the Caribbean Sea

The Caribbean Sea is a unique area geologically. It rides atop the small Caribbean Plate, a rigid relatively thin (100 to 150 km thick) piece of the Earth's crust (Figure 2-2; Kennett 1982). The small Caribbean Plate is sandwiched between the much larger North and South American Plates. When the edges of these plates meet, tectonic (structural) and seismic (earthquake) activity results. The Caribbean Plate moves roughly eastward while the North and South American Plates move roughly westward. It is, therefore, inevitable that the Caribbean and American Plates will meet or converge. The convergence of these plates occurs along the eastern boundary of the Caribbean Plate, under the Lesser Antilles island arc. In this region, the American Plates are driven under the Caribbean Plate in a process called subduction. Ocean trenches and island arcs characterize subduction zones.

As the Caribbean Plate continues to move eastward, sediments on top of the South American Plate are scraped off and accumulated into a large heap in the v-shaped void created by the subducting plates. The deformed sediments sometimes become massive enough that they reach the surface, forming an island. Barbados, the only non-volcanic island in the Lesser Antilles, was formed in this manner.

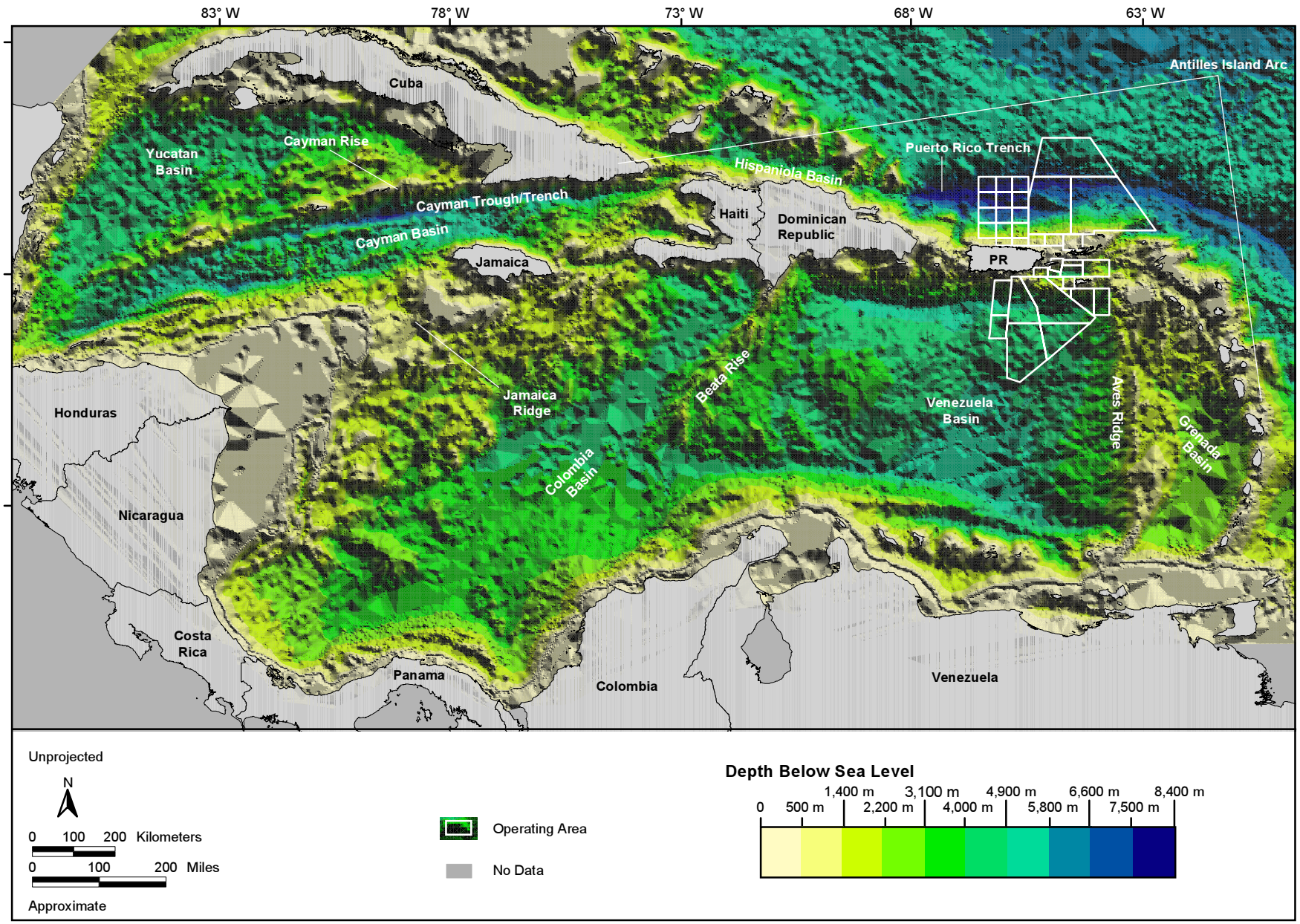

Figure 2-1. Physiography of the Caribbean Sea as shown by three-dimensional bathymetry. Source data: Smith and Sandwell (1997).

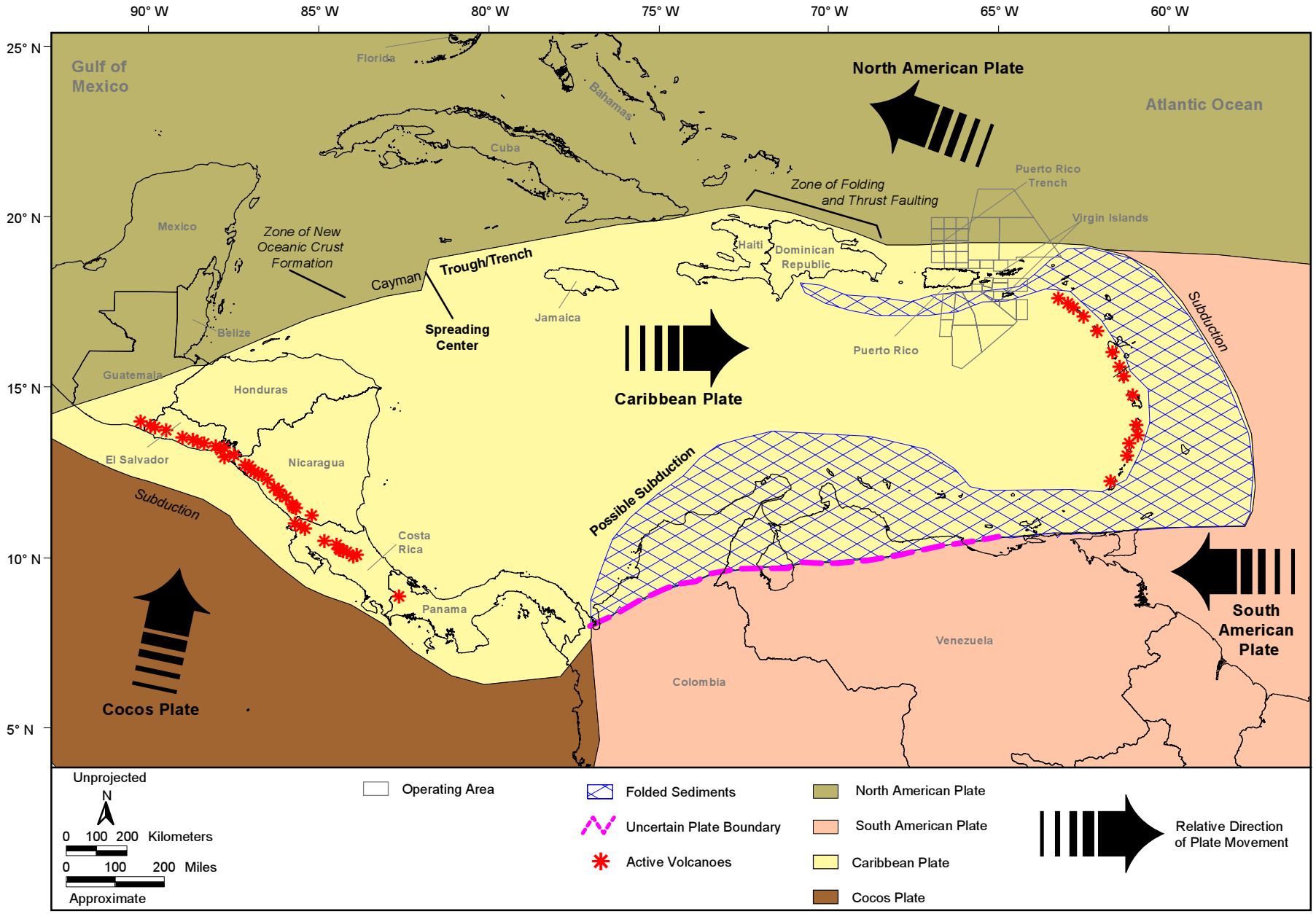

Figure 2-2. The boundary of the Caribbean Plate and its position and direction of movement relative to the surrounding North and South American Plates as well as the Cocos Plate. Source map (scanned): Dillon et al. (1987).

Active volcanoes and earthquakes are prevalent along the subduction zone beneath the islands of the Lesser Antilles (Kennett 1982). A band of earthquake activity defines the eastern boundary of the Caribbean Plate. Earthquakes in the area northeast of Anguilla are shallow, originating 10 to 20 km below the surface, while those whose epicenter is beneath the Lesser Antilles island arc deepen to >150 km (Dillon et al. 1988). About 200 earthquakes with magnitudes ranging from 2.5 to 5.9 on the Richter scale occurred between October 2001 and January 2002 in the ocean area north of Puerto Rico and the Virgin Islands; as recently as July 31, 2002, a magnitude 4.7 earthquake was registered in the British Virgin Islands (Shimel 2002; USGS 2002). Earthquakes occur in the eastern Caribbean due to the stress on the American Plates as they bend and descend beneath the Caribbean Plate in addition to the grinding action when the American Plates meet (Figure 2-2).

The plate substrate and accumulated sediments begin to melt as the American Plates descend into the Earth's superheated interior. The molten material is less dense and rises to the surface to form volcanoes. Volcanoes of the Lesser Antilles erupt explosively, as evidenced by the Montserrat eruptions of the 1990s. At the northeastern border of the Caribbean Plate north of Puerto Rico, subduction of the North American Plate continues. Little sediment is found on the subducting North American Plate, so no sediment is available to fill the deep void created by the subducting plate. Therefore, volcanoes did not form in this area but the deep void or trench remained. This is the location of the Puerto Rico Trench, the deepest trench found in the Atlantic Ocean (Figures 2-1 and 2-3).

The northern and southern sides of the Caribbean Plate are sliding past the American Plates while on the western plate boundary, another plate (Cocos) is being driven or subducted beneath the Caribbean Plate (Figure 2-2). The northern boundary of the Caribbean Plate is fairly straight except for two bends or deviations. These deviations in the linearity of the boundary and unceasing eastward movement of the Caribbean Plate have caused sediments to crumple and fold north of the Hispaniola Basin and a gap or opening to form between the Yucatan and Jamaica (Dillon et al. 1988). As this gap widened, molten material from the Earth's interior rose to fill the open space, the method in which new crust is formed. The opening resulted in the formation of the Cayman Trough or Trench (Figure 2-1). The southern boundary of the Caribbean Plate is fairly linear to the east and an arcing curve to the west. Compression at the curved area of the boundary causes major faults and uplift to occur. The western boundary where the Cocos and Caribbean Plates meet forms another subduction zone similar to that found on the eastern plate boundary. The layer of sediments on the subducting Cocos Plate are thin, so a deep (6 km) unfilled trench, similar to the Puerto Rico Trench, was formed (Dillon et al 1988).

2.1.2 Physiography and Bathymetry

The sea floor of the Caribbean Sea is characterized by trenches/troughs, island chains, and deep basins separated by a system of elevated, parallel ridges or rises (Figure 2-1). Jamaica Ridge, the elevated area stretching from the coasts of Honduras and Nicaragua towards Jamaica and terminating at Haiti, is the largest, at 644 km wide, in the Caribbean Sea. The majority of islands, rim the Caribbean (except in the southwest and west perimeters), but Jamaica and the Cayman Islands are found in the western interior atop the Jamaica Ridge and Cayman Rise. Venezuela Basin is the largest and deepest of the five basins within the Caribbean Sea. At its deepest point, 5,650 m, the sea floor is nearly flat (Avdeev and Beloussev 1971).

2.1.2.1 Continental Margins

Continental margins form the boundary or transition between the continents and the ocean basins. Simplistically, there are two types of continental margins: active (Pacific) and passive (Atlantic). Passive continental margins, such as the Atlantic coasts of North and South America, consist of three physiographic provinces that transition from one another with depth: continental shelf, continental slope, and continental rise. Passive margins are not plate boundaries but strictly distinguish the ocean-continent interface. They are stable and lack any seismic activity or volcanism. Active continental margins, as found on the western or Pacific coasts of North and South America, transition rapidly from continental shelf and slope to a deep trench; active margins mark the boundary between two converging crustal plates. Active margins are associated with seismic activity, volcanoes, trenches, and active mountain building.

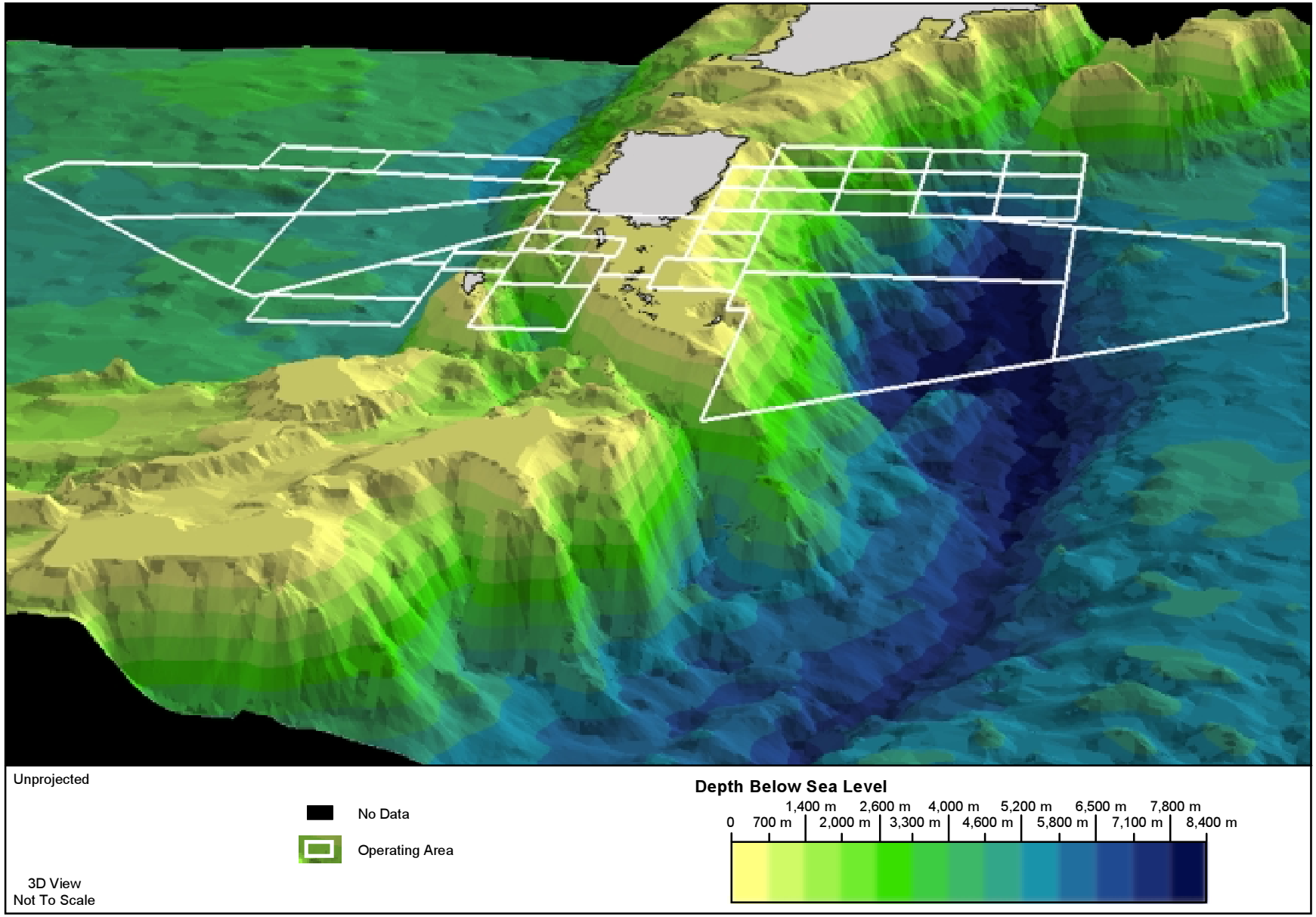

Figure 2-3. Three-dimensional bathymetric view of the Puerto Rico Trench and surrounding sea floor. Orientation of view is east to west. Source data: Smith and Sandwell (1997).

A third type of continental margin exists in the Caribbean region: the transform margin. Transform margins result from the horizontal movement of two crustal plates sliding along one another and are associated with shallow earthquakes (Kennett 1982). Seismic activity is possible at this type of margin but they can also be remarkably stable. This type of margin can be considered a hybrid between the other two types of margin, with some features of each margin type represented. For instance, the continental margin off Venezuela consists of a continental borderland similar to that found off California where the continental shelf is separated from the continental slope by islands and basins, as well as a continental terrace where there is a more typical transition from the continental shelf to the slope (Maloney 1971).

The eastern and northeastern parts of the Caribbean Sea are active continental margins while the north-central, northwestern, western, and southern Caribbean Sea boundaries are transform margins. It is not surprising then, that it is difficult to describe specifically the depths at which all the physiographic provinces are found in the Caribbean.

The continental shelf has little relief and is gently sloping with a seaward gradient of less than 1:1,000 (Kennett 1982). The width of the continental shelf and the depth at which it is found are highly variable throughout the Caribbean Sea. The width of Caribbean continental shelves ranges from 1.6 to 100 km with an average of approximately 45 km while the depth can vary from <10 m to 120 m compared to the world averages of 78 km and 130 m (Avdeev and Beloussev 1971; Mahoney 1971; Kennett 1982). The continental shelf break, where the gradient changes abruptly from the gentle slope of the shelf (<1:1,000) to the steep slope of the continental slope (1:40), marks the border of the continental shelf and beginning of the continental slope. In general, the depth of the continental shelf break from the Yucatan Peninsula to Venezuela is roughly 100 to 200 m except near the Panama Canal where it decreases in depth to 40 to 60 m (Avdeev and Beloussev 1971). The Caribbean insular shelf breaks are usually much shallower, however, extending from 10 to 140 m (Avdeev and Beloussev 1971).

The average depth to which the continental slope descends is 1,500 to 3,500 m worldwide and, in the Caribbean, the continental slope extends to the maximum depth of 3,600 m (Avdeev and Beloussev 1971). Continental rises are the deepest part of the continental margin and are found just above the ocean basin floor or abyssal plains. This province ranges in width from 100 to 1,000 km with a seaward gradient of 1:100 to 1:700 (Kennett 1982). In the Caribbean, continental rises are found on the flanks of the many ridges and rises that dominate the sea floor, terracing into the deep flat bottoms of the basins.

In the PROA/St. Croix OPAREA, the continental margin begins with an insular shelf called the Puerto Rico Platform, a carbonate and volcanic elevated plateau-like feature, which encompass the islands of Puerto Rico and all the Virgin Islands except St. Croix. The platform is about 40 to 48 km wide and 350 km long. The continental shelf break on the Puerto Rico Platform is highly variable in depth and marks the seaward perimeter of the platform. The water depths at which the shelf break occurs on the Puerto Rico Platform range from about 1 m to 100 m, although 40 m is the mean shelf-break water depth on the platform (Figure 2-4). The continental shelf on the northern side of Puerto Rico is very narrow, <1 to 3 km wide (Morelock 2000). The sea floor descends rapidly to the north of Puerto Rico to the deepest depths of the Atlantic Ocean. The Puerto Rico Platform shelf is very flat on the south and eastern sides of Puerto Rico. The insular platform shelf continues east from Puerto Rico to its terminus just east of Anegada Island, BVI. The shelf off southern Puerto Rico is the widest on the platform, ranging up to 21 km (Morelock 2000). The gradient of the continental slope is not as steep on the south side of Puerto Rico, where the depths descend into the Muertos Trough, at approximately 4,800 m. Between Vieques Island and St. Croix lies a deep hole, called the Virgin Island Trough or Basin, with depths approaching 5,000 m.

The vast majority of the PROA/St. Croix OPAREA lies over deep water (Figures 2-3 and 2-4). In the North PROA, water depths range from less than 100 m where the OPAREA boundary nears the coast of Puerto Rico to 8,400 m in the Puerto Rico Trench. The majority of the North OPAREA lies over waters averaging more than 5,000 m in depth. The waters underlying the South PROA are shallower than the North PROA, ranging from several hundred meters off southern Puerto Rico to 5,000 m, with the majority of the area lying over waters ranging in depth from 3,500 to 5,000 m deep.

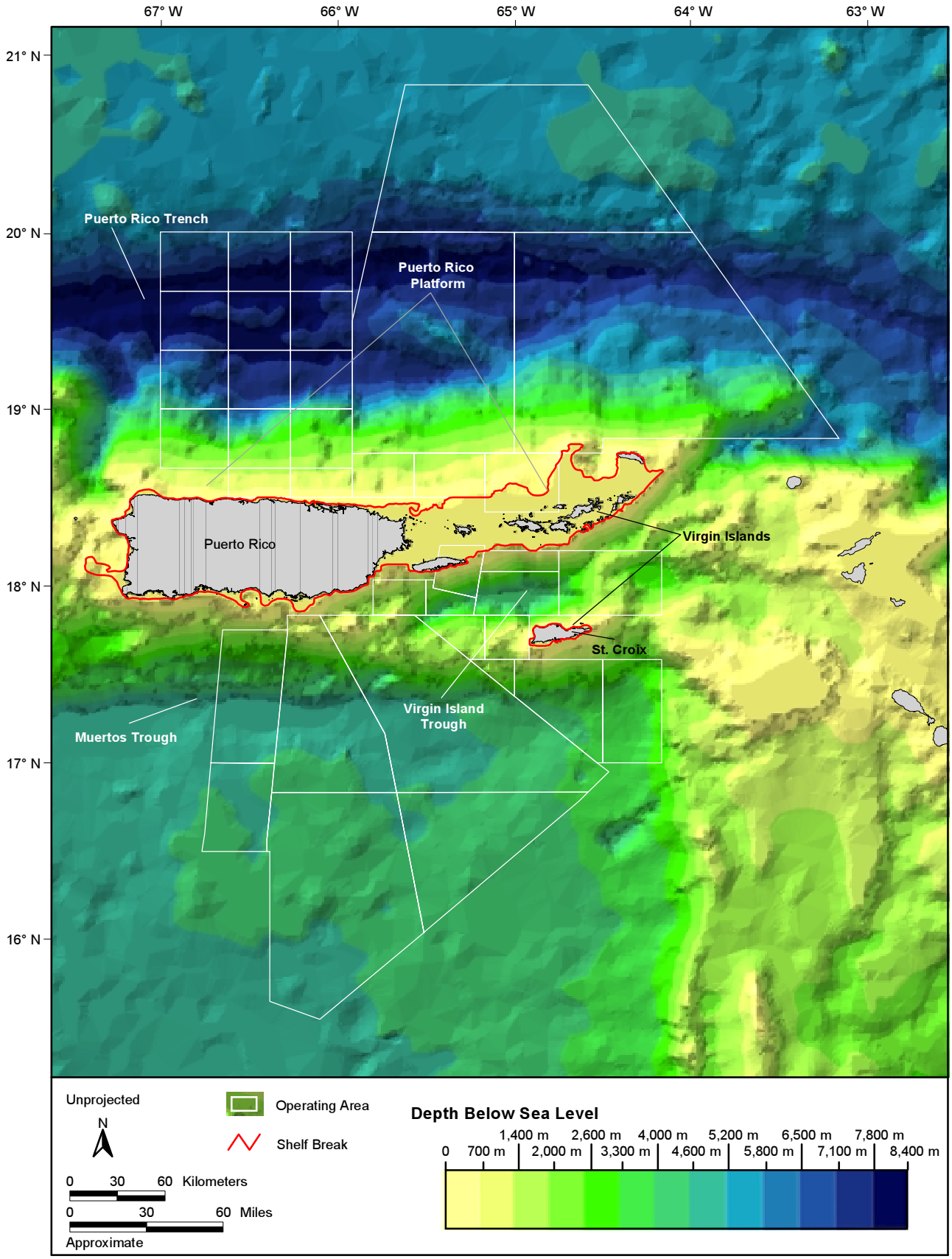

Figure 2-4. Sea floor bathymetry in the PROA/St. Croix OPAREA and vicinity. Source data: Smith and Sandwell (1997).

2.1.3 Bottom Substrate

The bottom sediments covering the sea floor in much of the Caribbean are primarily terrigenous in origin (sand, silt, mud, and clays). Sediments found on the insular shelves in the Caribbean are a combination of terrigenous and carbonate sediments. The Puerto Rico Platform is typical of insular shelves in the region with a mixture of carbonate sands, terrigenous sands, and terrigenous muds covering much of the platform, especially near the island shores. The north and western sections of the Puerto Rico Platform insular shelf and slope are covered with predominately terrigenous mud material composed of silt and clay as the result of river discharge on those shores. The majority of the remaining platform is covered with carbonate sands derived from calcareous animal skeletons. The upper slope of the insular slope is covered with a sandy mud that contains <50% sand (Morelock 2000).

2.2 PHYSICAL OCEANOGRAPHY

2.2.1 Water Masses, Currents, and Circulation

The waters of the Caribbean Sea are highly stratified in the upper 1,200 m of the water column but are weakly stratified with near homogeneous conditions below that (Gordon 1967). This structure is due primarily to the depths of the passages through which water from the Atlantic Ocean flows into the Caribbean. The Windward, Virgin, and Grenada Passages are the three primary entry points for inflowing Atlantic waters. Grenada Passage is slightly less than 1,200 m deep while the Virgin and Windward Passages are closer to 2,000 m deep (Gordon 1967).

The water column can be divided into essentially three separate layers or water masses: a surface water layer, a deepwater layer, and an intermediate area called the thermocline where the water temperature rapidly changes from the warmer surface water to the colder deep water. About 67% of the water in the North Atlantic Ocean can be found in the deep layer, 25% is found in the middle, thermocline layer, and 8% is composed of warm surface waters (Schmitz et al. 1987). Wind and water density differences drive the circulation of these water masses. Surface currents are primarily driven by the drag of the wind over the water surface. Wind-driven circulation affects primarily the upper 100 m of the water column. Variations in temperature and salinity cause differences in water density; these differences drive thermohaline or vertical circulation. Thermohaline circulation causes movement in water masses at all levels of the water column (i.e., deep and surface). The Caribbean Sea, however, lacks the temperature extremes and high evaporation rates necessary for thermohaline circulation to dominate (Gordon 1967).

2.2.1.1 Surface Currents

Surface water in the vicinity of the Caribbean Sea moves northwesterly, driven by the northeasterly Trade Winds. The dominant surface current in the Caribbean is the Caribbean Current (Figure 2-5). Just north of the Caribbean Sea, the Antilles Current dominates surface flow in the same westerly direction. The Antilles Current is part of the Western Boundary Current system that merges with the Florida Current and becomes the Gulf Stream, flowing northward along the U.S. east coast. The Antilles Current has a higher velocity than the Caribbean Current, with the maximum occurring in April through May.

The Caribbean Current enters the Caribbean Sea through the Grenada and St. Vincent Passages and travels nearly diagonally from southeast to northwest across the Caribbean. This current continues on through the Yucatan Straits into the Gulf of Mexico. There is seasonal variability in the flow of the Caribbean Current but not enough to disrupt the general pattern of transport (Kjerfve 1986).

2.2.1.2 Deepwater Currents/Water Masses

The cold, mid-depth and bottom waters of the Caribbean Sea are formed a great distance from this tropical area, in the subpolar regions of the Atlantic Ocean. The three cold, deeper water masses or currents found in the Caribbean Sea, Caribbean Bottom Water, North Atlantic Deep Water, and Subantarctic Intermediate Water, are driven by density rather than wind and are found in the deep basins

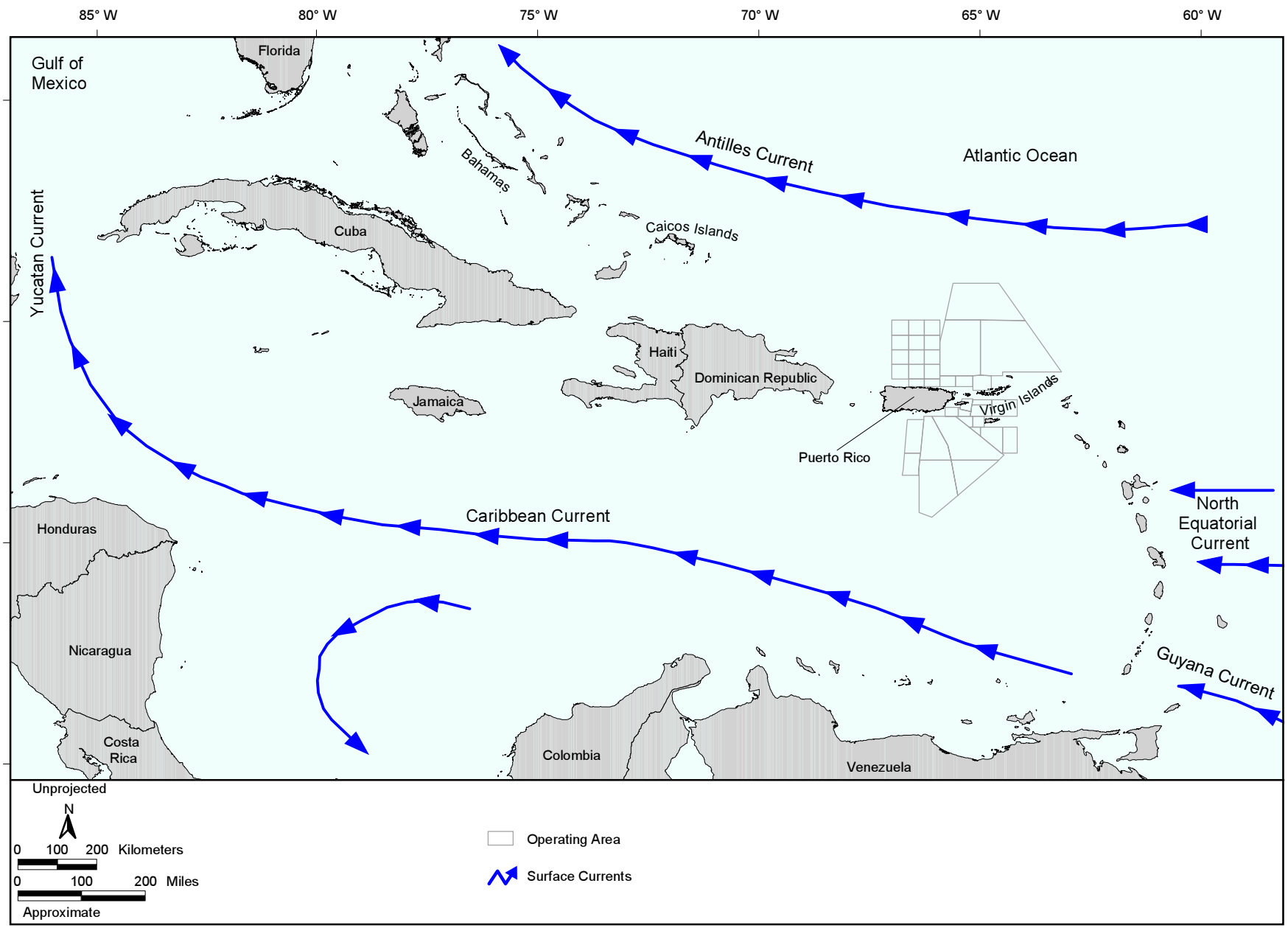

Figure 2-5. Surface circulation in the Caribbean Sea and surrounding waters. Source information: Pickard and Emery (1982).

of the Caribbean (Wüst 1964). These water masses enter the Caribbean Sea through the Grenada, Windward, and Virgin Passages.

- Caribbean Bottom Water—Caribbean Bottom Water (CBW) is the Antarctic Bottom Water equivalent in the Caribbean Sea. Antarctic Bottom Water (AABW) is formed by wintertime convection in the Southern Ocean, specifically in the Weddell Sea. Here, sea ice is formed, concentrating salt into the surrounding cold water and thus increasing its density. This very dense water sinks to the bottom and flows northward where it mixes with the warmer, more saline North Atlantic Deep Water (NADW). When AABW enters the Caribbean Sea, it is thereafter called CBW (Wüst 1964). The CBW current flows along the bottom of the Caribbean Sea southwesterly from the Virgin Passage into the Venezuela, Columbia, and Grenada Basins. CBW is characterized by salinities of 34.96 to 34.97 practical salinity units (psu). This water mass also enters the Caribbean through the Windward Passage and flows west into the Cayman Trough and Basin into the Yucatan Basin.

- North Atlantic Deep Water—The most abundant water mass in the North Atlantic Ocean is NADW, which is a mixture of water from several sources and is characterized by its high oxygen content (Wüst 1964). Iceland-Scotland Overflow Water crosses the Mid-Atlantic Ridge into the western basin of the North Atlantic through the Gibbs Fracture Zone (53°N) where it joins the Denmark Strait Overflow water. This combined flow mixes to form NADW and flows northward along the coast of Greenland, then southward along the Labrador coast, past the Grand Banks (Kennett 1982; Schmitz et al. 1987; Pickard and Emery 1990). Once this water mass reaches the continental slope, it is defined as the Western Boundary Under Current, which flows southwest along the continental rise below 2,000 m (Schmitz et al. 1987), crossing the Gulf Stream near Cape Hatteras. This southward flow is a permanent feature of the deep circulation of the Atlantic Ocean. The NADW can be considered as a countercurrent flowing beneath the Gulf Stream and beneath the Antilles Current at a rate of 6 to 18 cm/sec (Wüst 1964).

- Subantarctic Intermediate Water—Subantarctic Intermediate Water (SAIW) forms at 50°S and flows northward throughout the South Atlantic Ocean into the western North Atlantic Ocean. North of 40°S, SAIW extends over the entire Atlantic Ocean basin at depths of 700 to 900 m (Wüst 1964). As this water mass reaches 30°S, its spread and transport intensifies along South America due to the Coriolis effect. This water mass flows northwest and enters the Caribbean through the Grenada and St. Vincent Passages as a distinctive body of water with the characteristic salinity of 34.7 psu. SAIW flows through the Caribbean in the same path taken by the surface Caribbean Current.

2.2.1.3 Upwelling

Upwelling is the process by which surface water is replaced by deep water. Upwelling is a wind-driven or dynamic (through the interaction of currents, density, or bathymetry) process where warmer, nutrient-poor surface water is replaced by colder, nutrient- and oxygen-rich water from the depths (Mann and Lazier 1991). In wind-driven upwelling, surface water is horizontally transported perpendicular to the direction of the wind. Deep, cold water moves vertically to the surface to replace the surface water that was transported horizontally.

There are coastal areas of the world where persistent winds cause upwelling to occur nearly year-round. Major upwelling areas of the world are found off the coasts of Peru, California, and southwestern Africa. Upwelling usually leads to increased surface primary productivity as the higher concentrations of dissolved nutrients in the upwelled water spur growth and reproduction of phytoplankton.

Upwelling can also occur along ocean frontal boundaries. Upwelling usually leads to increased surface primary productivity as the higher concentrations of dissolved nutrients in the upwelled water spur growth and reproduction of phytoplankton. In the Caribbean Sea, persistent upwelling is found near the Columbia/Venezuela coasts (Kjerfve 1986).

2.3 HYDROGRAPHY

2.3.1 Temperature

The surface water temperatures of the Caribbean Sea do not vary greatly, as is expected from a tropical body of water. Sea surface temperatures in the winter range from 24°C to 26.5°C with summer temperatures averaging 27° to 30°C (Figure 2-6). Temperatures vary little across the Caribbean's surface during any season, but the warmest water temperatures are off Cuba in the summer while the coolest are off Venezuela in the winter, likely due to river discharge into the sea. Temperatures in the PROA/St. Croix OPAREA vary by only 1°C in each season, so that the surface waters are nearly homogeneous in temperature.

2.3.2 Salinity

The surface salinity of the Caribbean Sea is high, ranging from 33.5 to 36.0 psu in the summer and fall with little variability in the winter and spring seasons: 35.5 to 36.75 psu (Figure 2-7). The lowest salinities are found near the coast of South America and in the eastern Caribbean during the summer through fall, probably due to inflow of Orinoco River water into this area. Salinities increase in a westward direction so that highest salinities are found near Cuba during summer through fall. Surface salinities are highest near the coasts of Columbia and Venezuela in the winter and spring. During the winter and spring seasons, salinities in the surface waters of the PROA/St. Croix OPAREA are nearly uniform at 36 psu while more variation occurs in the summer and fall when salinities range from 34.5 to 36 psu in a south to north gradient through the OPAREA.

2.4 BIOLOGICAL OCEANOGRAPHY

Detailed descriptions of protected species such as marine mammals and sea turtles as well as species such as corals, seagrasses, and *Sargassum* that form specialized habitats may be found in later chapters of this MRA (Chapters 3, 4, and 5). In this section, the most important but often most neglected organisms, the plankton, are discussed with particular reference given to any physical mechanisms that affect their occurrence. Plankton are vital to life in the oceans as they form the base of the complex oceanic food webs, upon which higher organisms such as marine mammals, fish, and sea turtles depend.

2.4.1 Plankton

Plankton are pelagic organisms that float or drift and cannot maintain their direction against the movement of water masses (Parsons et al. 1984). They swim weakly or not at all. In a sense, they are at the mercy of their aquatic environment. Plankton are comprised of bacterioplankton (bacteria), zooplankton (animals) including ichthyoplankton (larval fish), and phytoplankton (plant-like). In general, this group of organisms is very small or microscopic, ranging to about 20 millimeters (mm) in size. There are exceptions; jellyfish and pelagic *Sargassum*, for example, are unable to move against the surrounding currents and therefore are considered part of the plankton group even though some jellyfish can grow to 3 m in diameter. Plankton are the most numerous organisms in the sea.

2.4.1.1 Phytoplankton

Phytoplankton are single-celled organisms that are similar to plants because they use sunlight and chlorophyll to photosynthesize. Phytoplankton are autotrophs and are the most important primary producers in most marine environments. Their growth and distribution are influenced by several factors, the most important of which are temperature (Eppley 1972), light (Yentsch and Lee 1966), and nutrient concentration (Goldman et al. 1979). Other factors such as pH and salinity also affect growth and production (Parsons et al. 1984). Phytoplankton distribution is patchy, occurring in environments that have optimal light, temperature, and nutrient conditions. In general, the concentration of phytoplankton will be higher in nearshore areas where there is input of nutrients from land sources. Phytoplankton use dissolved nitrogen (nitrate/nitrite/ammonia), phosphorous (phosphate), and silica (silicate) in their growth and photosynthetic processes. Phosphorous limitation is typical of freshwater systems and marine

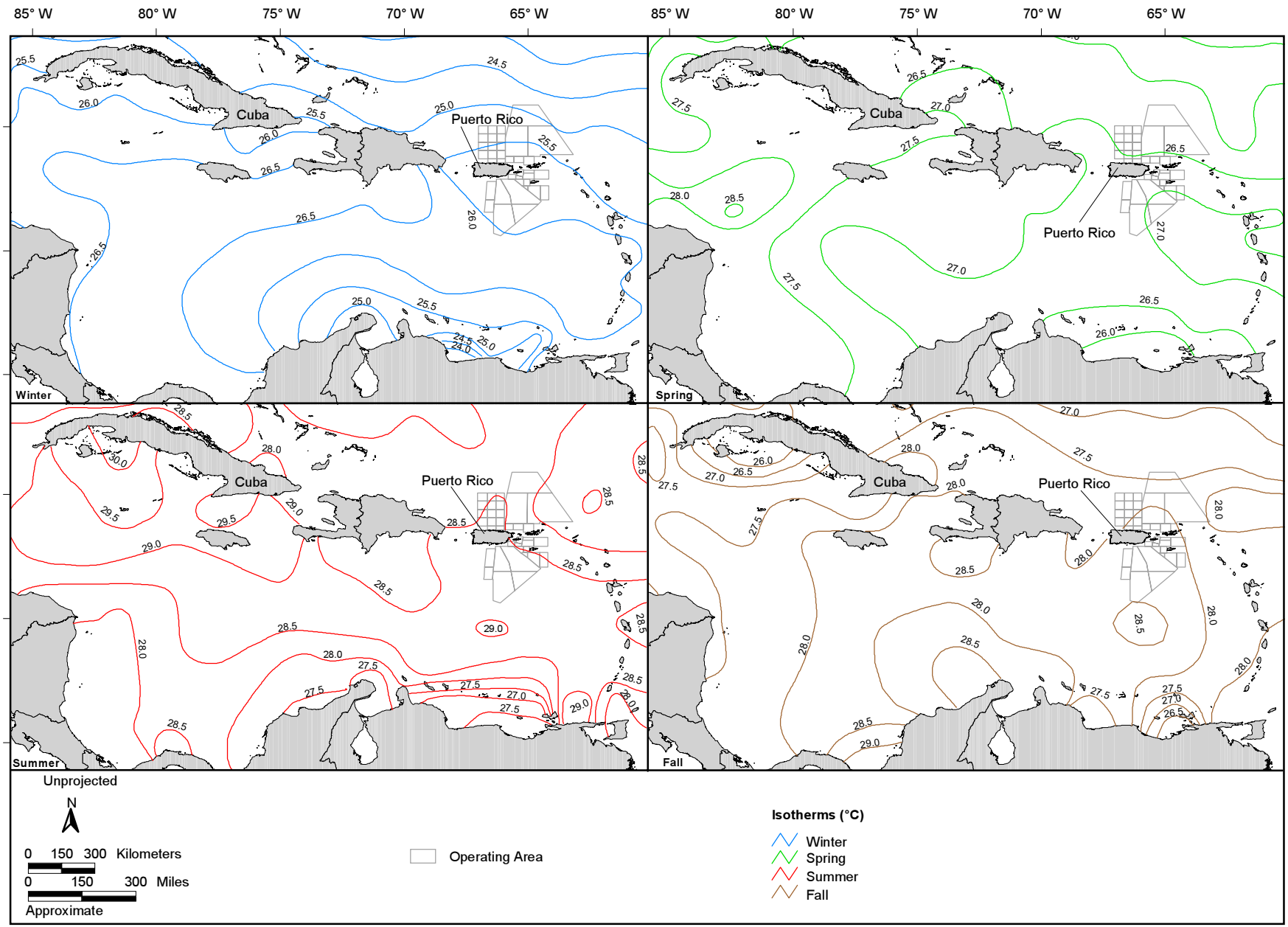

Figure 2-6. Mean seasonal sea surface temperatures in the Caribbean Sea from 1948 through 1970. Isotherms connect points of equal temperature and are contoured at 0.5°C intervals. Source map (scanned): Robinson (1973).

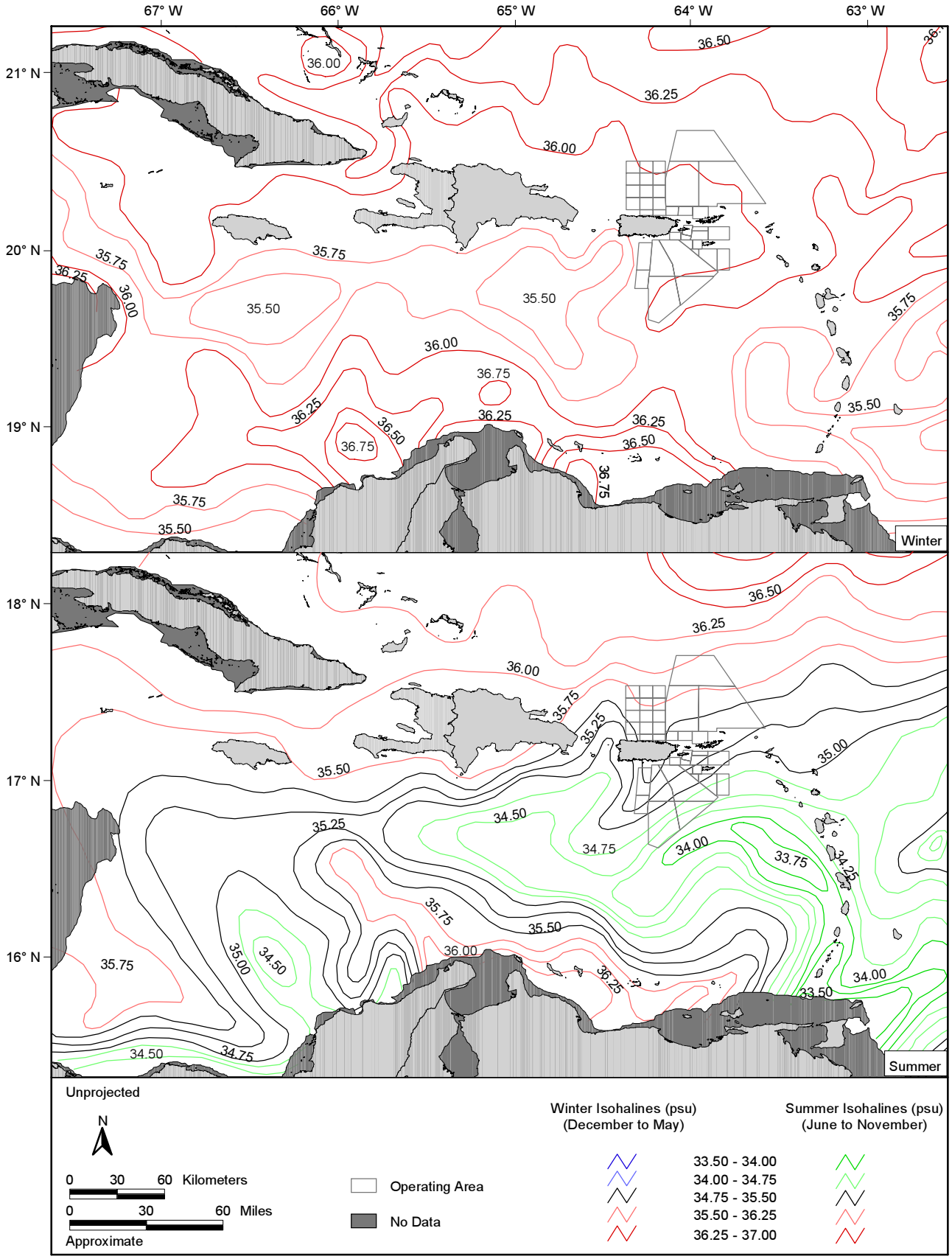

Figure 2-7. Mean surface salinities in the Caribbean Sea and vicinity compiled from 1901 through 1961 for two seasons: winter (December through May) and summer (June through November). Isohalines connect points of equal salinity. Source data: Wust (1964).

systems are more likely to be nitrogen limited. Important sources of nutrients in the Caribbean Sea are the discharge from the Orinoco River in northeastern Venezuela as well as the Amazon River, which is transported into the Caribbean Sea by currents and eddies from northeastern South America.

Composition of the phytoplankton community varies spatially and temporally. In general in the marine environment, the amount of primary production as well as the species diversity and biomass (total number) of phytoplankton decrease with increasing distance from shore. Primary production also decreases with increasing water depth. The most frequently used method to estimate phytoplankton biomass is by measuring the amount of chlorophyll *a* in the water column or at the sea surface. Thus, the concentration of chlorophyll *a* is often used as a proxy for phytoplankton biomass or abundance. Once the chlorophyll *a* concentration is known, the amount of primary production (or the amount of carbon produced) can also be obtained (Figure 2-8). Although the level of primary production and phytoplankton biomass is low in the oligotrophic (lacking nutrients) waters of the tropical Caribbean Sea, higher levels of primary productivity are present in the coastal waters surrounding many Caribbean islands, perhaps due to sewage and riverine discharge increasing the nutrient concentrations of these coastal waters. The waters off the coast of Venezuela are also higher in primary productivity (1,600 to 3,000 mg of C/m^2/day) than the surrounding Caribbean Sea waters, due largely to Orinoco River runoff, which supplies the nutrients needed for phytoplankton growth and reproduction. The majority of the eastern Caribbean, including the waters of the PROA/St. Croix OPAREA, supports about 200 to 800 mg of C/m^2/day of phytoplankton biomass (Figure 2-8).

2.4.1.2 Zooplankton

Zooplankton are aquatic animals ranging from the smallest protozoans to jellyfish (Wiebe et al. 1987). Although many are able to move sizable distances at moderate speeds and thus can perform diel vertical migrations of hundreds of meters, ocean currents and the suitability of the physical, chemical, and biological components of the hydrographic regimes they encounter determine their large-scale horizontal distributions.

In general, the biomass of zooplankton is higher in deeper water overlying the continental slope (as much as four times higher [Wiebe et al. 1987]). There is a spring enhancement of biomass within the upper 200 m (Wiebe et al. 1987). Increases in zooplankton biomass may occur when shelf water intrudes over slope water, creating a stratified water column. High nutrients and a shallow mixed layer will give rise to enhanced primary production, which in turn leads to an increase in zooplankton biomass or secondary production. In waters of the PROA/St. Croix OPAREA, copepods dominate the zooplankton with larger densities being found at night, verifying their diel migration (Youngbluth 1979). Significantly higher abundances of zooplankton were found during July in conjunction with the peak chlorophyll *a* concentrations and at the beginning of the seasonal salinity decrease in the waters south of Puerto Rico (Yoshioka et al. 1985). This suggests that upwelling at the edge of areas of low salinity is associated with increases in plankton abundance.

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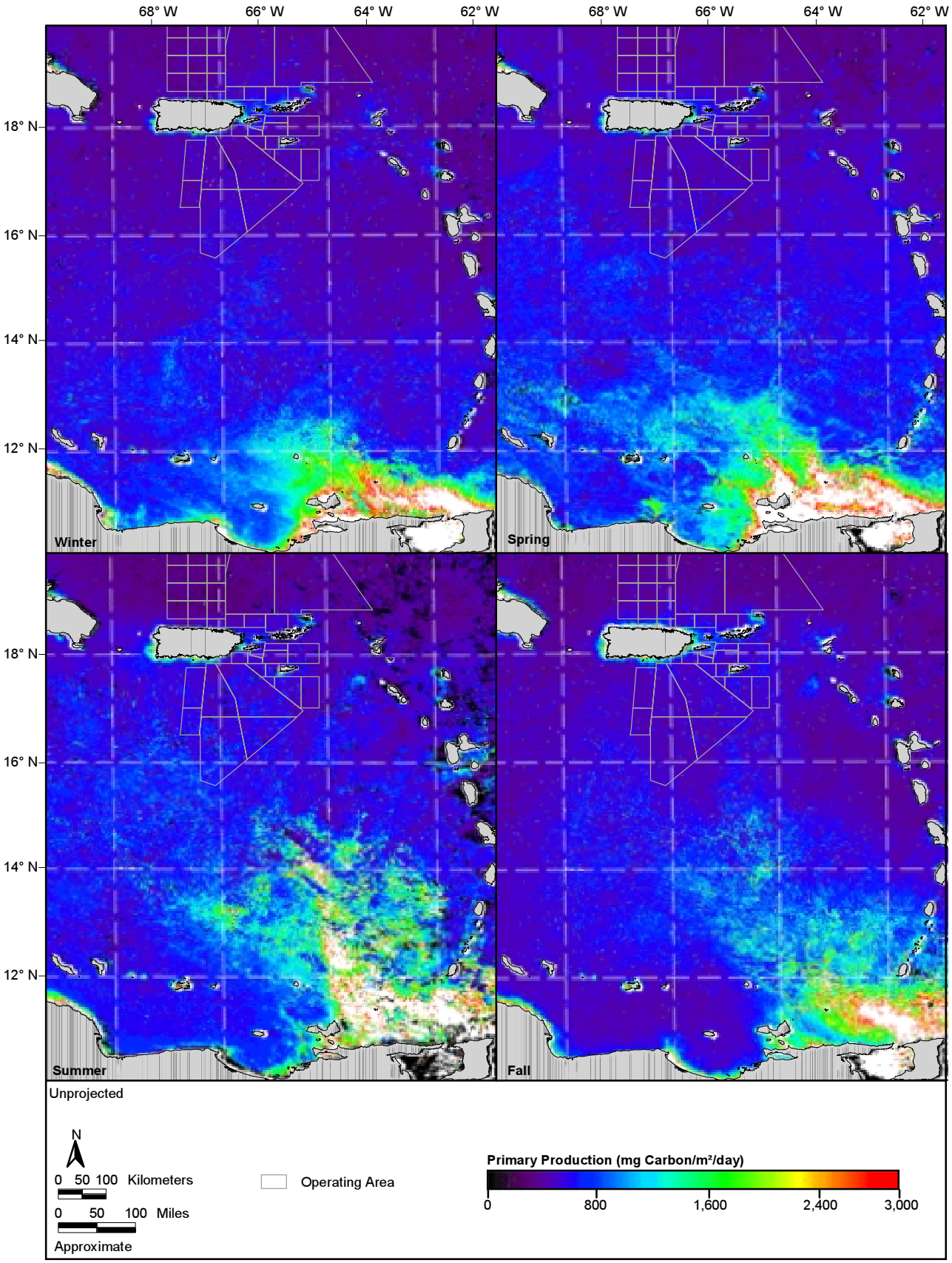

Figure 2-8. Seasonal primary production in the eastern Caribbean Sea as obtained by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) aboard the SeaStar satellite. Primary productivity is highest off the coast of Venezuela in all seasons and is highest along the southern coast of Puerto Rico in the summer and fall. Source map (scanned): UPRM (2002).

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3.0 SPECIES OF CONCERN

This chapter provides detailed information for marine mammals and sea turtles, which are species of particular interest to the Navy due to their protected status and which have the potential to be impacted by Navy activities.

Section 3.1 furnishes information on the 31 marine mammal species with confirmed or possible occurrence in the PROA/St. Croix OPAREA. All marine mammals are protected by the MMPA; five large whale species and the West Indian manatee are additionally listed as endangered under the ESA. The section provides an overview of marine mammals, as well as a brief introduction to acoustics and hearing, which is useful in consideration of any potential acoustic anthropogenic impacts to these animals. Each species has a detailed narrative, which provides a description of the species, its status, habitat preferences, distribution (including a focus on the OPAREA), behavior and life history, as well as an account of its vocalizations and hearing capabilities (when available). Maps depicting the seasonal occurrence of each species in the OPAREA may be found in Appendix B (Figures B-1 through B-26). Also located in Appendix B are the seasonal listings of the distribution of marine mammal records by OPAREA surface grid block (Tables B1 through B4).

Section 3.2 begins with an overview of the biology and life history of sea turtles and, like the marine mammal section, also provides some basic information on the hearing capabilities of these animals. All six sea turtle species occurring in the PROA/St. Croix OPAREA are listed as threatened or endangered. Each of these sea turtle species is then described in detail with the same basic framework in section 3.1. Maps depicting the seasonal occurrence of each species in the OPAREA may be found in Appendix C (Figures C-1 through C-6); also located in Appendix C, Table C-1, is the distribution of sea turtle records by OPAREA surface grid block.

3.1 MARINE MAMMALS

3.1.1 Introduction

There are 31 marine mammal (cetacean, pinniped, and sirenian) species with possible or confirmed occurrence in the PROA/St. Croix OPAREA (Table 3-1). Toothed and baleen whales (cetaceans) are the most abundant types of marine mammal species occurring in the Caribbean. Toothed whales (odontocetes) capture their prey using teeth, while baleen whales (mysticetes) filter their food from the water by using baleen plates. The West Indian manatee is the only sirenian species occurring in this area. The Caribbean monk seal (*Monachus tropicalis*) was present in the Caribbean until the 1950s, but is now considered extinct (Le Boeuf et al. 1986). Puerto Rico, the U.S. Virgin Islands (USVI), and British Virgin Islands (BVI) have never been considered a locality where Caribbean monk seals were usually found (Mignucci-Giannoni 1989), though hooded seals occasionally wander into this area (Mignucci-Giannoni and Odell 2001; Mignucci-Giannoni and Haddow 2002).

3.1.1.1 Adaptations to the Marine Environment: Sound Production and Reception

Cetaceans display a number of anatomical and physiological adaptations to an aquatic environment that are discussed in detail by Pabst et al. (1999). Sensory changes from the basic mammalian scheme have also taken place in response to the different challenges an aquatic environment imposes. Sound travels further in water than in air, and is therefore, an important sense, although taste, touch, and sight are also well developed in whales and dolphins (Wartzok and Ketten 1999). Marine mammal vocalizations often extend both above and below the range of human hearing; those with frequencies lower than 18 hertz (Hz) are labeled as infrasonic and those higher than 20 kilohertz (kHz) as ultrasonic. Baleen whales primarily use the lower frequencies, producing tonal sounds in the frequency range of 20 to 3,000 Hz, depending on the species. The toothed whales produce a wide variety of sounds, which include species-specific broadband “clicks” with peak energy between 10 and 200 kHz, individually variable burst pulse click trains, and constant frequency or frequency modulated whistles ranging from 4 to 16 kHz (Wartzok and Ketten 1999). Many toothed whales produce both tonal vocalizations (whistles) used for communication and broadband clicks used during echolocation (Wartzok and Ketten 1999). Sperm whales, however, are known to produce only clicks, which may be used for communication and echolocation. Data on the hearing abilities of cetaceans are sparse, particularly for the larger cetaceans such as baleen whales. The auditory thresholds of some of the smaller odontocetes have been determined in captivity. It is generally believed that cetaceans should at least be sensitive to the frequencies of their own vocalizations. Comparisons of the anatomy of cetacean inner ears and models of the structural properties and the response to vibrations of the ear’s components in different species provide an indication of likely sensitivity to various sound frequencies. The ears of small toothed whales are optimized for receiving high frequency sound, while baleen whale inner ears are best in low to infrasonic frequencies (Ketten 1992, 1997). General reviews of cetacean sound production and hearing may be found in Richardson et al. (1995), Edds-Walton (1997), Wartzok and Ketten (1999), and Au et al. (2000). For a discussion of acoustic concepts, terminology, and measurement procedures, as well as underwater sound propagation, Urick (1983) and Richardson et al. (1995) are recommended.

3.1.1.2 Marine Mammal Distribution and Habitat Associations

Cetaceans inhabit most marine environments, from deep ocean canyons to shallow estuarine waters. Habitat and distribution of cetaceans are affected by various components of the ocean environment as well as demographic, evolutionary, and anthropogenic factors (Bjørge 2002; Forcada 2002; Stevick et al. 2002). Cetacean species occurring off the continental shelf are often associated with physical forms such as banks, canyons or the edge of the continental shelf, which may concentrate prey (Kenney and Winn 1986; Davis et al. 1998). In many areas, movements may also be related to the presence of hydrographic features, in particular, upwelling events (Griffin 1999; Biggs et al. 2000). The increased nutrient concentrations associated with these events result in areas of high primary productivity. These areas of higher primary production cause a cascading effect on the trophic dynamics of marine animals and are generally associated with higher than normal levels of consumers such as cetaceans and their prey.

Table 3-1. Marine mammal species of the PROA/St. Croix OPAREA and their status under the Endangered Species Act (ESA). Taxonomy follows Rice (1998) for pinnipeds and sirenians and IWC (2001) for cetaceans.

	Scientific Name	ESA Status
Order Cetacea		
Suborder Mysticeti (baleen whales)		
Family Balaenopteridae (rorquals)		
Humpback whale	*Megaptera novaeangliae*	Endangered
Minke whale	*Balaenoptera acutorostrata*	
Bryde's whale	*Balaenoptera edeni*	
Sei whale	*Balaenoptera borealis*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Suborder Odontoceti (toothed whales)		
Family Physeteridae (sperm whale)		
Sperm whale	*Physeter macrocephalus*	Endangered
Family Kogiidae (pygmy sperm whales)		
Pygmy sperm whale	*Kogia breviceps*	
Dwarf sperm whale	*Kogia sima*	
Family Ziphiidae (beaked whales)		
Cuvier's beaked whale	*Ziphius cavirostris*	
True's beaked whale	*Mesoplodon mirus*	
Gervais' beaked whale	*Mesoplodon europaeus*	
Blainville's beaked whale	*Mesoplodon densirostris*	
Sowerby's beaked whale	*Mesoplodon bidens*	
Family Delphinidae (dolphins)		
Rough-toothed dolphin	*Steno bredanensis*	
Common bottlenose dolphin	*Tursiops truncatus*	
Pantropical spotted dolphin	*Stenella attenuata*	
Atlantic spotted dolphin	*Stenella frontalis*	
Spinner dolphin	*Stenella longirostris*	
Striped dolphin	*Stenella coeruleoalba*	
Clymene dolphin	*Stenella clymene*	
Common dolphins	*Delphinus* spp.	
Fraser's dolphin	*Lagenodelphis hosei*	
Risso's dolphin	*Grampus griseus*	
Melon-headed whale	*Peponocephala electra*	
Pygmy killer whale	*Feresa attenuata*	
False killer whale	*Pseudorca crassidens*	
Killer whale	*Orcinus orca*	
Short-finned pilot whale	*Globicephala macrorhynchus*	
Order Carnivora		
Suborder Pinnipedia (seals, sea lions, walruses)		
Family Phocidae (true seals)		
Hooded seal	*Cystophora cristata*	
Order Sirenia		
Family Trichechidae (manatees)		
West Indian manatee	*Trichechus manatus*	Endangered

Hydrographic features are dynamic; therefore, cetaceans occurring off the continental shelf or away from the shelf break will also have a dynamic distribution as they seek out these patches of good habitat.

Whale and dolphin movements are often related to feeding or breeding activity (Stevick et al. 2002). Some baleen whale species, such as humpback and North Atlantic right whales, make extensive annual migrations to low-latitude mating and calving grounds in the winter and to high-latitude feeding grounds in the summer (Corkeron and Connor 1999). These migrations undoubtedly occur during these seasons due to the presence of highly productive waters and associated cetacean prey species at high latitudes and of warm water temperatures at low-latitudes (Corkeron and Connor 1999; Stern 2002). The question remains as to why some baleen whale species migrate to warm waters for reproduction (Stern 2002). Not all baleen whales, however, migrate. Some individual fin, Bryde's, minke, and blue whales may stay year-round in a specific area. The timing of migration is often a function of age, sex, and reproductive class. Females tend to migrate earlier than males and adults earlier than immature animals (Stevick et al. 2002). Since most toothed whales do not have the fasting capability of the baleen whales, toothed whales probably follow seasonal shifts in preferred prey or are opportunistic feeders, taking advantage of whatever prey happens to be in the area.

As already noted, cetacean movements are often a reflection of the distribution and abundance of prey (CETAP 1982; Gaskin 1982; Payne et al. 1986; Kenney et al. 1996). Cetacean movements have also been linked to indirect indicators of prey, such as temperature variations, sea-surface chlorophyll *a* concentrations, and features such as bottom depth (Fiedler 2002). Occurrence of cetaceans outside the area with which they are usually associated may reflect fluctuations in food availability. In some areas, these changes have been correlated with large-scale climatic events (El Niño and La Niña) that affect the normal distribution of prey. For example, during La Niña events cold-water currents flow closer to shore, bringing prey commonly associated with deeper waters into coastal areas. During these times, oceanic marine mammal species may be seen closer to shore (Bryant et al. 1981; Whitehead and Carscadden 1985; Payne et al. 1986; Selzer and Payne 1988; Kenney et al. 1996). A strong El Niño event in 1982 through 1983 affected the distribution of pilot whales off southern California when the influx of warm water caused squid not to spawn as usual in the area (Shane 1994). Short-finned pilot whales were virtually absent from the region during that time and did not reappear for another nine years. During the same El Niño event, coastal bottlenose dolphins expanded their range from southern to central California and remained in the new northern range even after the warming event subsided (Wells et al. 1990). Sperm whales in the eastern tropical Pacific had reduced calf survival during and after an El Niño event in the late 1980s (Whitehead 1997). High pinniped mortalities have been reported during El Niño events; many pups died of starvation because their mothers spent longer times at sea foraging (Domingo et al. 2002). While the effects on marine mammals attributable to El Niño and La Niña events have been most significant and well documented in the Pacific Ocean, these large-scale events do affect the Atlantic Ocean and may therefore cause perturbations in the distribution of marine mammals in that ocean basin. No specific documentation exists on El Niño and La Niña trophic effects in the Atlantic Ocean but the distribution and location of prey species may be affected by even minor climatic fluctuations. Recent research indicates that the North Atlantic Oscillation may be a more significant climatic driver in the Atlantic Ocean that El Niño (Stenseth et al. 2002). Further research will demonstrate the strength of this event on trophic regimes in the Atlantic.

Climatic fluctuations have produced a growing concern about the effects of climate change on cetacean populations (MacGarvin and Simmonds 1996; IWC 1997; Evans 2002; Würsig et al. 2002). Long-term temperature trends may play a role in the distribution and abundance of cetacean species, either affecting them directly or indirectly, through alterations of habitat characteristics and distribution, and prey availability (Kenney et al. 1996; IWC 1997; Harwood 2001).

3.1.2 Marine Mammals of the PROA/St. Croix OPAREA

The varied physiography of the Caribbean Sea, with deep basins, oceanic islands, and narrow continental or insular shelves provides a diverse range of habitats for a variety of marine mammal species. Most species, such as the West Indian manatee or bottlenose dolphin, utilize this area year-round. Others species, such as the endangered humpback whale, have a seasonal occurrence. Some animals, such as

the hooded seal, occasionally travel into the Caribbean Sea, a region far beyond their normal distributional range.

Marine mammals often occur in the PROA/St. Croix OPAREA and vicinity on a seasonal basis but others occur in the area year-round (Appendix B Tables B-1 through B-4). Seasons refer to the typical three-month intervals utilized throughout the MRA report (winter=January through March; spring=April through June; summer=July through September; fall=October through December). It should be noted that the number of marine mammal observations in a given area is often as much a function of the source or type of data (bycatch data versus data collected by aerial or shipboard surveys), level of survey effort, and sighting conditions (such as calm seas) as the actual abundance of marine mammals in that area.

All available marine mammal sighting (aerial and ship), stranding, and incidental fisheries bycatch occurrence records (Appendix A, Table A-2) were used to predict the spatial and temporal occurrences of the 31 marine mammal species that may occur in the OPAREA and vicinity. An occurrence record does not reflect the number of marine mammals; due to the social nature of cetaceans, multiple individuals of a species are often sighted at the same time at the same location. Therefore, the occurrence records shown on the map figures that accompany this section represent the number of data records collected, not the number of marine mammals observed. The process by which the occurrence predictions and map figures were created is described in detail in Section 1.4.2.2.

Various types of shading and terminology are used on the map figures to designate the occurrence of marine mammals in the PROA/St. Croix OPAREA and vicinity. “Expected occurrence” (area shaded in light blue) is defined as the area encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and the available sighting, stranding, incidental fisheries bycatch, and tagging data. “Concentrated occurrence” (area shaded in dark blue) is the subarea of a species' expected occurrence where there is the highest likelihood of encountering that species; the designation is based primarily on areas of concentrated sightings and preferred habitat. “Low/unknown occurrence” (pattern-filled area) is the area where the likelihood of encountering a species is rare or not known. “Occurrence not expected” (white, unmarked area) is the area where a species is not expected to occur.

Winter is the season with the highest number of marine mammal occurrence records (161 occurrence records; Table B-1), while summer has the least (38 occurrence records; Table B-3). Spring and fall have an intermediate number of occurrence records (42 occurrence records; Table B-2 and 40 occurrence records; Table B-4, respectively). The greatest total number of individual marine mammals represented by occurrence records is found in the winter and spring (1,762 and 1,575, respectively), while summer has the least (308). It is probable that there are many more individual marine mammals and greater species diversity occurring in the PROA/St. Croix OPAREA than are represented in Tables B-1 to B-4, as survey effort is limited in the OPAREA (Appendix Figure A-1).

Marine mammals are found throughout the PROA/St. Croix OPAREA, with large numbers of sightings occurring on the insular shelf of the Puerto Rico Platform (Appendix Figure B-1). Manatees are found in coastal waters, well inside the continental shelf and, rarely, if at all, near the shelf break (Mignucci-Giannoni 1989). This distribution is probably more a reflection of the topography and substrate requirements for seagrasses, which manatees feed upon (Mignucci-Giannoni 1989). The distribution of cetaceans near Puerto Rico and the Virgin Islands is highly correlated to the area's bathymetric relief (Mignucci-Giannoni 1989, 1998). In a review of the available information prior to any systematic cetacean surveys in this area, Mignucci-Giannoni (1989, 1998) determined that most marine mammal species occur on the continental shelf. With deep water (>200 m) in very close proximity to the shore in the northeastern Caribbean Sea, there are many oceanic cetacean species that may be found near shore or on the continental shelf in contrast to locales in other parts of the world where the continental shelf is wider.

The large number of marine mammal sightings on the continental shelf also may be a reflection of survey effort. Survey efforts directed towards humpback whales traditionally have been conducted in shallow waters located over sand banks or close to islands of their calving grounds, since this is the preferred

habitat of humpback whales mother-calf pairs. As manatees are coastal animals, directed surveys have taken place in the nearshore waters off the islands of Puerto Rico and Vieques. The Navy has focused efforts during its training exercises to ascertain the occurrence of protected marine mammals and sea turtles in the Inner Range surrounding Vieques Island. There has been very little survey effort, however, in deep waters (Figure A-1; Roden and Mullin 2000; Swartz et al. 2001, 2002).

The seasonal abundance and distribution of most cetacean species in the northeastern Caribbean is poorly known (Mignucci-Giannoni 1989; Mignucci-Giannoni et al. 1999a; Roden and Mullin 2000; Swartz et al. 2002). Mignucci-Giannoni (1989, 1998) reported that more cetaceans were sighted during the winter and early spring. This increase is likely a reflection of highly seasonal survey effort. The survey effort has been biased to the winter months because of focused efforts to determine the distribution and abundance of the humpback whale during its calving season (winter and spring) (Appendix Figure A-1). It is logical that there are also a larger number of sightings of other marine mammals during that time of year. With surveys recently being conducted in deeper waters, the distribution of many of the cetacean species in this area has been found to extend off the shelf break into deeper waters (Roden and Mullin 2000; Swartz et al. 2001, 2002). Based on the known habitat preferences of many of these species, it is quite likely that extensive dedicated survey effort will reveal an even larger number of cetacean sightings along the continental shelf break and high sea floor relief.

Each marine mammal species is listed below with its description, status, habitat preferences, distribution (including location and seasonal occurrence in the PROA/St. Croix OPAREA), behavior and life history, as well as information on its acoustics and hearing ability. Species appearance within the text begins with threatened and endangered marine mammals and the remaining marine mammal species follow the taxonomic order as presented in Table 3-1.

3.1.2.1 Threatened and Endangered Marine Mammal Species of PROA/St. Croix OPAREA

Six marine mammal species with possible or confirmed occurrence in the PROA/St. Croix OPAREA are currently listed as endangered: four baleen whale species (blue, fin, humpback, and sei whales), one toothed whale species (sperm whale), and one sirenian, the West Indian manatee.

All available endangered marine mammal sightings, strandings, and incidental fisheries bycatch records for the PROA/St. Croix OPAREA have been compiled so predictions can be made regarding the seasonal usage of the OPAREA by endangered marine mammals (Appendix Figure B-2). The occurrence predictions were developed using all available data as well as the known distribution, habitat preference, and seasonal occurrence from published literature on the endangered whale and manatee species. Unidentified rorquals (the family of baleen whales which includes the blue, fin, minke, Bryde's, sei, and humpback whales) were included to conservatively determine endangered whale occurrence for the PROA/St. Croix OPAREA. Considering unidentified rorquals, though this category includes the non-endangered/non-threatened minke and Bryde's whales, is appropriate in determining endangered whale occurrence in the PROA/St. Croix OPAREA since most of the rorquals are endangered species. The West Indian manatee occurs in nearshore waters, and while its distribution is not expected to extend into deep waters, part of the OPAREA does include coastal waters of islands, which are known manatee habitat.

During all seasons, the expected occurrence for endangered marine mammals is based primarily on the occurrence of the sperm whale but the humpback whale and West Indian manatee occurrence patterns were also considered. During all seasons, endangered marine mammals in the PROA/St. Croix OPAREA are expected to occur on the Puerto Rico Platform's insular shelf outward into open ocean waters (Figure B-2).

During all seasons except summer, the concentrated occurrence of endangered marine mammals covers the Puerto Rico Platform or the insular shelf of the islands within the PROA/St. Croix OPAREA. In summer, there is only a low/unknown occurrence of marine mammals on the insular shelf, based primarily on manatee occurrence records for this season.

There are areas of expected, concentrated, or low or unknown occurrence of endangered marine mammals close to shore (depending on suitable habitat for manatees) on the continental shelf around the islands (for more detailed information see the OPAREA-specific information for the West Indian manatee). There is also a low or unknown occurrence of endangered marine mammals from the 30 m isobath to the continental shelf break, which is based on the possibility of encountering sperm whales in waters on the continental shelf (but not close to the shoreline). The continental shelf is narrow in this area and deep waters are close to shore. Like the rest of the year, there is also an area of low or unknown occurrence seaward of the area of expected occurrence. There is a low or unknown occurrence for the group in waters seaward of the area of expected occurrence. This is based on the few sightings of endangered marine mammals in such deep waters, which are a result of few dedicated large-scale survey efforts.

- Humpback Whale (*Megaptera novaeangliae*)

  Description—Humpback whale adults are 11 to 16 meters (m) in length and are more robust than other rorquals (Jefferson et al. 1993). The body is black or dark gray, with very long (about a third of the body length), usually white flippers (Jefferson et al. 1993; Clapham and Mead 1999). The flukes have a concave, serrated trailing edge; the ventral side is patterned in black and white. Individual humpback whales may be identified using these patterns (Katona et al. 1979).

  Status—The humpback whale is classified as an endangered species under the ESA. There are an estimated 10,600 humpback whales in the entire North Atlantic (Smith et al. 1999). Mattila and Clapham (1989) reported a density of 0.044 humpback whales per square nautical mile for the Virgin Islands. A similar density is expected for Puerto Rico (Mignucci-Giannoni 1998). During February through March 2000, acoustic detections of singing humpback whales in the eastern and southern Caribbean Sea formed the basis of a preliminary estimate of the relative abundance of humpback whales in the islands and coastal areas surveyed to be 116 whales in February and 123 in March (Swartz et al. 2001). These results suggest that the abundance of humpbacks in the eastern and southern Caribbean Sea is lower than it was during the nineteenth century. Observed densities were one or two orders of magnitude lower than those recorded from the primary wintering areas in the eastern Greater Antilles. Swartz et al. (2002) provide a provisional abundance estimate of 532 humpback whales on the Puerto Rico Bank during the February through March time frame.

  Habitat Preferences—The habitat requirements of wintering humpbacks appear to be determined by the conditions necessary for calving. Optimal calving conditions are warm waters (24° to 28°C) and relatively shallow, low-relief ocean bottom in protected area (behind reefs) to take advantage of calm seas, minimize the possibility of predation by sharks, or avoid harassment by males (Clapham 2000). Whaling data indicate that the eastern and southern Caribbean Sea formerly supported a large-scale fishery for humpback whales, exploiting the known occurrence of humpback whales in shallow waters (Price 1985). Mignucci-Giannoni (1998) found that humpback whales are associated with banks and other shallow waters with low sea floor relief. Distribution seems to concentrate on the windward side of landmasses, in banks of a certain width, such as Borinquen and Virgin banks (Mignucci-Giannoni 1998). Humpback whales on the calving grounds have also been sighted in deeper water (>183 m; deepest sighting of a cow-calf pair was in waters with a bottom depth of 5,124 m, north of the Mona Passage) (Roden and Mullin 2000; Swartz et al. 2002).

  In the northern feeding grounds, favored habitat is typically shallow banks and shoals or areas with high seafloor relief (CETAP 1982; Payne et al. 1990). The most important feeding habitat is the shallow southwestern Gulf of Maine from Jeffreys Ledge south to the Great South Channel.

  Distribution—Humpback whales are found in all of the world's oceans (Jefferson et al. 1993). They generally are found during the summer on high-latitude feeding grounds and during the winter in the tropics around islands, over shallow banks, and along continental coasts, where calving occurs. In the North Atlantic, humpback whales are found from the Caribbean Sea and Cape Verde Islands in the south to Greenland, Iceland, and northern Norway (Rice 1998). Most humpback whale sightings are in nearshore and continental shelf waters; however, humpback whales frequently travel through deep water during migration (Clapham and Mattila 1990).

In the North Atlantic, humpbacks are found from spring through fall on feeding grounds, which are located from south of New England to northern Norway (NMFS 1991). The largest numbers of humpback whales are from mid-April to mid-November. Locations off the northeastern U.S. include Stellwagen Bank, Jeffreys Ledge, the Great South Channel, the edges and shoals of Georges Bank, Cashes Ledge, Grand Manan Banks; the banks on the Nova Scotian Shelf; the Gulf of St. Lawrence; and Newfoundland's Grand Banks (CETAP 1982; Whitehead 1982; Kenney and Winn 1986; Weinrich et al. 1997). Humpback whales return to the same feeding areas each year. There appears to be very little exchange between the six separate "feeding stocks": Gulf of Maine, Gulf of St. Lawrence, Newfoundland/Labrador, western Greenland, Iceland, and Norway (Katona and Beard 1990; Clapham 1996).

Humpback feeding grounds are likely to be less consistent over the long term since their prey are much more mobile and their diet is more flexible. The distribution and abundance of sand lance are important factors underlying the distribution patterns of the humpback whale (Kenney and Winn 1986). Changes in diets and feeding preferences are likely caused by changes in prey distribution and/or in the relative abundance of different prey species (sand lance and herring) (Payne et al. 1986, 1990; Kenney et al. 1996; Weinrich et al. 1997). Feeding most often occurs in relatively shallow water over the inner continental shelf, sometimes in deeper waters. Large multi-species feeding aggregations (including humpback whales) have been observed over the shelf break on the southern edge of Georges Bank (CETAP 1982; Kenney and Winn 1987) and in shelf break waters off the U.S. mid-Atlantic coast (Smith et al. 1996).

During the winter, most of the North Atlantic population of humpback whales is believed to migrate south to calving grounds in the West Indies region (Winn et al. 1975; Whitehead and Moore 1982; Stevick et al. 1998; Smith et al. 1999). The calving peak for the species is January through March, with some animals arriving as early as December and a few not leaving until June. Most of the humpback whales photo-identified off Puerto Rico and the Virgin Islands have been photographed on the Newfoundland/Labrador grounds and in the Gulf of Maine (Mattila and Clapham 1989). Photo-identification matches also demonstrate that all humpback whales off Iceland winter in Caribbean waters (Martin et al. 1984). Humpback whales wintering in the West Indies belong to a single population that distributes itself throughout the region during the winter. The whaling data demonstrate that humpback whales were formerly common throughout the Lesser Antilles, along the Caribbean coast of Venezuela, in the Gulf of Paria (located in northeast South America between Trindiad and Venezuela), and along the southern coast of Trinidad during January through May (Reeves et al. 2001).

Humpback whales in the northeastern Caribbean Sea are primarily found on Borinquen, Virgin, and Anguilla Banks (Figure 3-1; Mattila and Clapham 1989; Swartz et al. 2002). Mignucci-Giannoni (1998) observed two major areas of humpback whale concentration: one along the northwestern coast of Puerto Rico and the second widely spread around the northern Virgin Islands. Jobsis et al. (2001) noted that most humpback whales in the U.S. Virgin Islands are reported near St. Thomas and St. John rather than St. Croix. Humpback whales have been sighted off Vieques Island and between Culebra and Vieques (Erdman et al. 1973). Stevick et al. (1999) reported photographic matches of an individual in Puerto Rico and Dominica, demonstrating an exchange between the eastern Caribbean and more northerly breeding area in the Greater Antilles.

Apparently, not all Atlantic humpback whales migrate to the calving grounds, since some sightings (believed to be only a very small proportion of the population) are made during the winter in northern habitats (CETAP 1982; Whitehead 1982; Clapham et al. 1993; Swingle et al. 1993). There has been an increasing occurrence of humpback whales during the winter along the U.S. Atlantic coast, from Florida north to Virginia, which appear to be primarily juveniles (Swingle et al. 1993; Clapham et al. 1993; Wiley et al. 1995; Laerm et al. 1997). Strandings of humpbacks (mainly juveniles) in this area have also increased in recent years (Wiley et al. 1995). These occurrences are not fully understood. They might be due to shifts in distribution, increases in sighting effort, or habitat that is becoming increasingly important for juveniles (Waring et al. 2002). Sighting histories of mature humpback

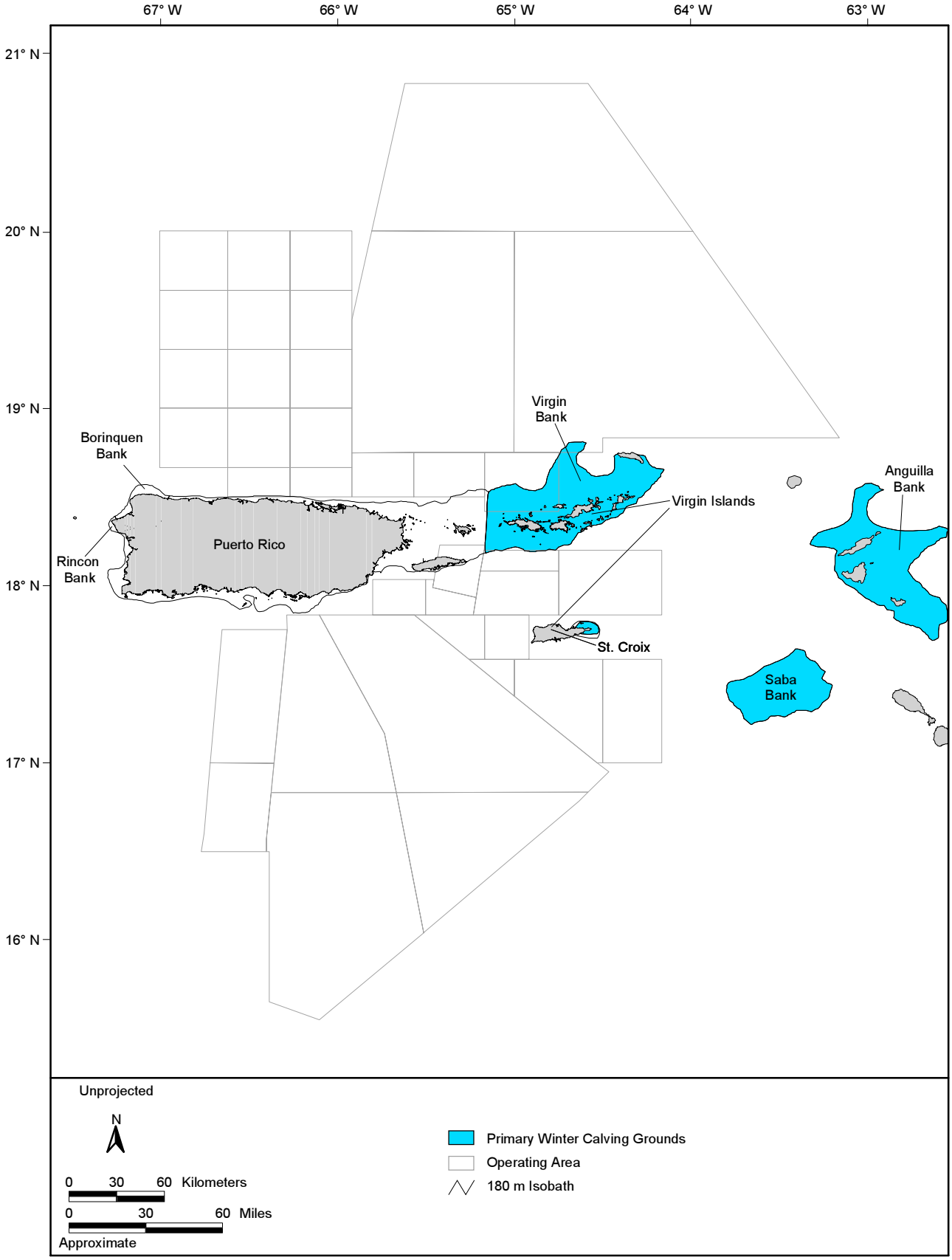

Figure 3-1. The primary winter (calving) grounds of the humpback whale in the PROA/St. Croix OPAREA and vicinity. Source information: Mattila and Clapham (1989) and Swartz et al. (2002).

whales suggest that the mid-Atlantic area contains a greater percentage of mature animals than is represented by strandings (Barco et al. 2001). It has recently been proposed that the mid-Atlantic region primarily represents a supplemental winter-feeding ground, which is also an area of mixing of humpback whales from different feeding stocks (Barco et al. 2001).

The migratory routes taken during the southbound and northbound migrations are not known. Since large numbers of humpback whales are not observed close to shore during this time, it is presumed that whales travel the more direct routes in deeper, offshore waters (Smith et al. 1999). Lactating females are among the first to leave summer feeding grounds in the fall, followed by subadult males, mature males, non-pregnant females, and pregnant females (Clapham 1996). During the northward migration, the whales are not believed to separate into discrete feeding groups until north of Bermuda (Katona and Beard 1990).

- Information Specific to PROA/St. Croix OPAREA—Based on sightings, strandings, and life history parameters, the humpback whale is expected during all seasons, except summer, in the PROA/St. Croix OPAREA (Figure B-3). Humpback whales migrate to calving grounds in the Caribbean during the fall, overwinter, and then make return migrations to the feeding grounds much further north during the spring. Humpback whales are not expected in the PROA/St. Croix OPAREA during summer since they should already be found further north on their feeding grounds.

  Humpback whales are expected to be found in insular shelf waters of the Puerto Rico Platform to waters as deep as 3,000 m to the north of Puerto Rico in the Puerto Rico trench and to 1,000 m to the south of Puerto Rico. The insular shelf waters of the Puerto Rico Platform are considered an area of concentrated occurrence based on the habitat preferences of mother-calf pairs for shallow waters (Clapham 2000) and the higher percentage of sightings occurring there.

  The occurrence of humpback whales beyond the 1,000 and 3,000 m isobaths is low or unknown based on data from recent acoustic and visual surveys by Swartz et al. (2001, 2002), as well as historic sighting data from whaling logs (Reeves et al. 2001). Reeves et al. (2001) inferred from sighting data that humpback whales may move across deep water within the eastern Caribbean region. Swartz et al. (2002) noted a conspicuous absence of humpback whales in the waters nearshore and offshore of the southern coast of Puerto Rico. An acoustic and visual survey of the waters around St. Kitts and Nevis, BVI documented humpback whale calls emanating from Saba Bank, southeast of St. Croix, USVI (Swartz et al. 2001). Humpback whale calls were detected from whales located to the northeast and east of the Puerto Rican Trench over deep water (>6,000 m) and far from any banks or islands (Swartz et al. 2002). The same surveys obtained data suggesting that some distant humpback whales were located to the south of Puerto Rico in deep water (depth unknown) at some yet to be determined position (Swartz et al. 2002). As noted by Swartz et al. (2002), the only land south of Puerto Rico is the small island of Aves located in the middle of the Venezuela Basin. The authors noted that it is not known if humpback whales aggregate at or near Isla Aves or follow the Aves Ridge to the east when migrating up and down the eastern Caribbean island chain.

Behavior and Life History—Single individuals are observed most commonly. On the feeding grounds, relatively large numbers of humpbacks may be observed within a limited area feeding on a rich food source (CETAP 1982). On the breeding grounds, small groups of males may occur, competing for access to females. Rough-toothed dolphins and short-finned pilot whales are occasionally seen in association with humpback whales in the northeastern Caribbean (Mattila and Clapham 1989; Roden and Mullin 2000).

Humpback whales feed like most other rorquals by “gulping” (Pivorunas 1979). Humpbacks use a wide variety of behaviors to feed on various small, schooling prey including krill and fish (Jurasz and Jurasz 1979; Hain et al. 1982, 1995; Weinrich et al. 1992). The principal fish prey in the western North Atlantic are sand lance (*Ammodytes americanus*), herring (Family Clupidae), and capelin (*Millotus villoses*) (Kenney et al. 1985). Feeding is thought to be limited to the higher latitudes (the

feeding grounds); however, Mignucci-Giannoni (1989) reported observations of feeding behaviors on the calving grounds.

Female humpbacks become sexually mature at 4 to 9 years of age (Clapham 1996). Gestation is approximately one year. Calves are weaned before one year of age. Calving intervals are usually 2 to 3 years but occasionally females give birth to calves in successive years (Clapham 1996). Males compete for access to receptive females by aggressive, sometimes violent interactions as well as vocal displays (Clapham 1996). The calving peak is January through March; sightings have been reported between November and May. The peak of the calving season occurs by the first two weeks of February through the middle of March (Mignucci-Giannoni 1998).

Humpback whale diving behavior depends on the time of year (Clapham and Mead 1999). In summer, most dives last less than 5 minutes (min) and dives exceeding 10 min are atypical. In winter (December through March), dives average 10 to 15 min; dives exceeding 30 min have been recorded (Clapham and Mead 1999).

Acoustics and Hearing—Humpback whales are known to produce three classes of vocalizations: (1) "songs" in the late fall, winter, and spring by solitary males; (2) sounds made within groups on the wintering (calving) grounds; and (3) sounds made on the feeding grounds (Thomson and Richardson 1995). Components of the song range from under 20 Hz to 4 kHz and occasionally 8 kHz, with source levels of 144 to 174 decibels with a reference pressure of 1 micropascal at one meter (dB re 1 μPa-m), with a mean of 155 dB re 1 μPa-m. Social calls are from 50 Hz to over 10 kHz with dominant energy below 3 kHz. Feeding calls are 20 Hz to 2 kHz, <1 second (sec) in duration, and with source levels of 175 to 192 dB re 1 μPa-m. Houser et al. (2001) recently produced the first predicted humpback audiogram (using a mathematical model). The predicted audiogram indicates sensitivity to frequencies from 700 Hz to 10 kHz, with maximum relative sensitivity between 2 and 6 kHz. Au et al. (2001) recorded high-frequency harmonics (out to 13.5 kHz) and source levels (between 171 and 189 dB re 1 μPa-m) of humpback whale songs.

- Sei Whale (*Balaenoptera borealis*)

Description—Adult sei whales are up to 18 m in length and are mostly dark gray in color with a lighter belly (Jefferson et al. 1993). There is a single prominent ridge on the rostrum and a slightly arched rostrum with a downturned tip (Jefferson et al. 1993). The dorsal fin is prominent and very falcate. Sei whales are extremely similar in appearance to Bryde's whales and it is difficult to differentiate them at sea and even on the beach (Mead 1977).

Status—Sei whales are listed as endangered under the ESA. The International Whaling Commission recognizes three sei whale stocks in the North Atlantic: Nova Scotia, Iceland-Denmark Strait, and Northeast Atlantic (Perry et al. 1999). The most current (1991) population estimate for the entire North Atlantic Ocean is 4,000 sei whales (Perry et al. 1999).

Habitat Preferences—Sei whales appear to prefer regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins situated between banks and ledges (Hain et al. 1985; Kenney and Winn 1987; Schilling et al. 1992). These areas are often the location of persistent oceanographic features, which may be important factors in concentrating prey. Catches of sei whales in the North Pacific were correlated with oceanographic features (Nishiwaki 1966).

Distribution—Sei whales are found in all oceans but are more restricted to mid-latitude temperate waters than other rorquals (Gambell 1985a). Like other rorquals, they undertake long migrations during spring and fall (Rice 1998). Sei whales are also known for irruptive occurrences in areas where they are not typically seen (Payne et al. 1990; Schilling et al. 1992).

In the western North Atlantic, sei whales occur primarily from Georges Bank north to Davis Strait (northeast Canada, between Greenland and Baffin Island) (Perry et al. 1999). Sei whales are not known to be common in U.S. Atlantic waters (Mead 1977; NMFS 1998a). Peak abundance in U.S.

waters occurs in spring (mid-March through mid-June), primarily along the edges of Georges Bank (CETAP 1982). The distribution of the Nova Scotia stock might extend along the U.S. coast to at least North Carolina (NC) (NMFS 1998a).

- Information Specific to PROA/St. Croix OPAREA—Sei whales are not expected to occur in this OPAREA; they are not generally found in waters this far south in the northern hemisphere (Jefferson personal communication). There is one confirmed stranding record for the northeastern Caribbean, from the Dominican Republic in July 1974 (Mead 1977). Mead (1977) suggested this individual might be from a separate population than those occurring farther north. Two rorquals sighted west of Anegada, British Virgin Islands (BVI) in 1967 were speculated to be sei whales (Erdman 1970; Erdman et al. 1973). Mignucci-Giannoni (1989) reported that Jiménez (1983) provided a sighting of one individual rorqual from 1982 and determined it to be a sei whale. Jiménez (1983) does not contain the actual record, which was provided directly to Dr. Antonio Mignucci-Giannoni for inclusion in his database (Mignucci-Giannoni personal communication). Neither photos nor clear diagnostic features were provided for either of the two sightings; the species identification was based on behavioral characteristics. Therefore, these are not confirmed records; misidentifications are likely to be of Bryde's whales (Jefferson personal communication).

Behavior and Life History—Sei whales are typically found in groups of 1 to 5 individuals (Leatherwood et al. 1976). The sei whale is atypical as a rorqual in that it primarily "skims" its food (though it does some some "gulping" as other rorquals do) (Pivorunas 1979). In the North Atlantic, the major prey species are copepods and krill (Kenney et al. 1985). Sei whales typically follow a reproductive cycle of two years: a gestation period of about 10 to 12 months and a lactation period of 6 to 9 months (Gambell 1985a).

Acoustics and Hearing—Sei whale vocalizations have been recorded only on a few occasions. Vocalizations consist of paired sequences (0.5 to 0.8 sec, separated by 0.4 to 1.0 sec) of 7 to 20 short (4 milliseconds [msec]) frequency-modulated (FM) sweeps between 1.5 and 3.5 kHz; source level is not known (Thomson and Richardson 1995). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- Fin Whale (*Balaenoptera physalus*)

Description—Fin whales are the second-largest whale species, with adults reaching 24 m in length (Jefferson et al. 1993). Fin whales have a very sleek body, with a pale, V-shaped chevron on the back, just behind the head. The dorsal fin is prominent, but with a shallow leading edge and is set back two-thirds of the body from the head (Jefferson et al. 1993). The head color is asymmetrical, with a lower jaw that is white on the right and black or dark brown on the left. Fin and sei whales are very similar in appearance, which has resulted in confusion about the distribution of either species (NMFS 1998a).

Status—The ESA lists the fin whale as an endangered species. The entire North Atlantic population may number as many as 50,000 to 60,000 animals (Perry et al. 1999). There is no stock information for fin whales in the Caribbean Sea.

Habitat Preferences—Fin whales in the U.S. Atlantic occur in continental shelf and shelf-edge waters from the Gulf of Maine south to Cape Hatteras, NC (CETAP 1982; Hain et al. 1992; Waring et al. 2002). The fin whale appears to be scarce in offshore slope and Gulf Stream waters (CETAP 1982; Waring et al. 1992). This species tends to aggregate in locations where prey is most plentiful, though those locations may shift seasonally or annually (Payne et al. 1986, 1990; Kenney et al. 1997). Relatively consistent locations for fin whales include the same habitats noted previously for humpback whales (with some additional areas) including the banks on the Nova Scotian shelf, Georges Bank, Jeffreys Ledge, Stellwagen Bank, the Great South Channel, Long Island, off Block Island (southeast of Long Island), and along the shelf break of the northeastern U.S. (CETAP 1982; Hain et al. 1992; Waring et al. 2002). Hain et al. (1992) reported that the single most important habitat was a region from the western Gulf of Maine, to Jeffreys Ledge, Cape Ann, Stellwagen Bank, to the

Great South Channel, in approximately 90 m of water. This was an area of high prey (sand lance) density during the 1970s and early 1980s (Kenney and Winn 1986). Secondary areas of important fin whale habitat included the shelf break from the Northeast Peak of Georges Bank to the mid-Atlantic and the mid-shelf from south of New England to the Mid-Atlantic Bight. Waring and Finn (1995) found a significant relationship in the distributions of fin whales and sand lance in the fall. In the lower Bay of Fundy, fin whales occur in areas with high topographic variation that are likely well mixed or contain frontal interfaces between mixed and stratified waters, and which concentrate krill and herring (Woodley and Gaskin 1996).

Distribution—Fin whales are broadly distributed throughout the world's oceans, in both continental shelf and deep waters (Rice 1998). The overall range of fin whales in the North Atlantic extends from the Gulf of Mexico/Caribbean and Mediterranean north to Greenland, Iceland, and Norway (Gambell 1985b; NMFS 1998a). In general, fin whales are more common north of about 30ºN (NMFS 1998a). In the western North Atlantic, the fin whale is the most commonly sighted large whale in continental shelf waters from the mid-Atlantic coast of the U.S. to eastern Canada (CETAP 1982; Hain et al. 1992; Waring et al. 2002). The fin whale is the most common whale species acoustically detected via Navy deepwater hydrophone arrays in the North Atlantic (Clark 1995). Fin whales are the dominant large cetacean species in all seasons in this area; they have the largest standing stock and food requirements (Hain et al. 1992; Kenney et al. 1997).

Fin whales are believed to follow the typical baleen whale migratory pattern, with a population shift north into summer feeding grounds and south for the winter. However, the location and extent of the wintering grounds are poorly known (Aguilar 2002). Fin whales were acoustically detected in winter throughout the deep waters of the North Atlantic, supporting the widely held hypothesis about their migration (Clark 1995). Acoustic detections of fin whales in offshore waters peaked in winter. The study showed a definite movement of fin whales southward in the fall and northward in the spring; in the western North Atlantic the end points of most of the migrations were Newfoundland/Labrador and south of Bermuda into the West Indies. Migration routes are otherwise unknown.

Fin whales are not completely absent from U.S. Atlantic continental shelf waters in winter; this is the most likely large whale species to be sighted. Perhaps a fifth to a quarter of the spring/summer peak population remains in this area year-round (CETAP 1982; Hain et al. 1992).

- Information Specific to PROA/St. Croix OPAREA—Fin whales were sighted in both winter and spring, which may reflect some differences in migration patterns, with some individuals leaving later than others (Figure B-4). Acoustic detections of fin whales showed a definite southward movement of fin whales in the fall and northward in spring; in the western North Atlantic the end points of most of the migrations were Newfoundland/Labrador and south of Bermuda into the West Indies (Clark 1995).

  The winter range of most rorquals (blue, fin, sei, and minke whales) is suggested to be in offshore waters (Kellogg 1928; Gaskin 1982). Acoustic data support the hypothesis of an offshore wintering habitat (Clark 1995). The sighting data, however, indicate that fin whales are also being sighted on the continental shelf (Figure B-4). There are very few confirmed sightings of this species in the OPAREA.

  The endangered status of this large whale species was heeded when determining its occurrence. The distribution of unidentified rorquals (this group includes the Bryde's whale, fin whale, blue whale, minke whale, humpback whale, and sei whale, which can be difficult to distinguish from one another during some sighting conditions; Figure B-5) was also considered in creating the map for Figure B-4. Most of these sightings are thought to be Bryde's whales, but sightings past the shelf break might be of fin whales (Jefferson personal communication). It would be reasonable to assume that a number of the sightings that were recorded as unidentified rorquals might be of fin whales.

There is a low or unknown occurrence of fin whales throughout the PROA/St. Croix OPAREA during fall, winter, and spring (Figure B-4). During the summer, fin whales should be found on their feeding grounds further north off the northeastern U.S. and are not expected to occur in this OPAREA during this time of year.

Behavior and Life History—Fin whales feed by "gulping" (Pivorunas 1979) and prey upon a wide variety of small, schooling prey (especially herring, capelin, and sand lance), including squid, krill and copepods (Kenney et al. 1985; NMFS 1998a). Single fin whales are most common. Fin whales are frequently observed in large multi-species feeding aggregations with humpback whales, minke whales, and Atlantic white-sided dolphins (CETAP 1982).

Female fin whales in the North Atlantic mature at 8 to 11 years of age (Boyd et al. 1999). Peak calving is in October through January (Hain et al. 1992) after a gestation period of approximately 11 months. Weaning may occur at 6 months (Boyd et al. 1999).

Fin whale dives are typically 5 to 15 min, separated by sequences of 4 to 5 blows at 10 to 20 sec intervals (CETAP 1982; Stone et al. 1992). Kopelman and Sadove (1995) found significant differences in blow intervals, dive times, and blows per hour between surface-feeding and non-surface-feeding fin whales. Croll et al. (2001) found that fin whales dived to 97.9 (± standard deviation [S.D.] 32.59) m with duration of 6.3 (±S.D. 1.53) min when foraging and to 59.3 (±S.D. 29.67) m with duration of 4.2 (±S.D. 1.67) min when not foraging. Fin whale dives exceeding 150 m and coinciding with the diel migration of krill were reported by (Panigada et al. 1999).

Acoustics and Hearing—Fin whales produce a variety of sounds with a frequency range up to 750 Hz. Infrasonic signals have been documented for fin whales (Watkins et al. 1987). The most typical fin whale sound is a 20 Hz infrasonic pulse (actually an FM downward sweep from about 23 to 18 Hz) with duration of about 1 sec and a typical source level of 160 to 186 dB re 1 μPa-m (maximum to 200) (Thomson and Richardson 1995; Charif et al. 2002). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- Blue Whale (*Balaenoptera musculus*

Description—Blue whales are the largest living animals. Blue whale adults in the northern hemisphere reach 22.9 to 28 m in length (Jefferson et al. 1993). The rostrum of a blue whale is broad and U-shaped, with a single prominent ridge down the center. There is a small, variably shaped dorsal fin far back on the tail (Leatherwood and Reeves 1983). This species is blue-gray with light mottling on the back and sides.

Status—Blue whales are classified as endangered under the ESA. The blue whale was severely depleted by commercial whaling (NMFS 1998b). There are no current statistically reliable estimates of abundance for the North Atlantic blue whale population (Perry et al. 1999). There is no stock information for blue whales in Caribbean waters.

Habitat Preferences—Globally, blue whales are primarily found in deeper, offshore waters and are rare in shallower, shelf waters (Wenzel et al. 1988). In the Gulf of St. Lawrence, however, blue whales show strong preferences for the nearshore regions, where strong tidal and current mixing leads to high productivity and rich prey resources (Sears et al. 1990).

Distribution—Blue whales are distributed from the ice edge to the subtropics in both hemispheres (Jefferson et al. 1993). Stranding and sighting data suggest that the blue whale's original range in the Atlantic extended south to Florida, the Gulf of Mexico, the Cape Verdes islands, and the Caribbean Sea (Yochem and Leatherwood 1985). Researchers using Navy integrated undersea surveillance system (IUSS) assets have been able to detect blue whales throughout the open Atlantic south to at least the Bahamas (Clark 1995), suggesting that North Atlantic blue whales may comprise a single stock (NMFS 1998b). The only Caribbean record for a blue whale is from San Cristobal at the northern entrance to the Panama Canal in 1922 (Harmer 1923).

- Information Specific to PROA/St. Croix OPAREA—There are no records for blue whales in the PROA/St. Croix OPAREA (Appendix Figure B-6). As noted earlier, the only Caribbean record is from near the Panama Canal (Harmer 1923). The blue whale is primarily an oceanic species. Croll et al. (1999) note that the winter grounds and southern limits of the blue whale in the North Atlantic are not known. Therefore, there is a low or unknown occurrence of blue whales from the shelf break to past the boundaries of the OPAREA, which takes into consideration the endangered status of this species, this species' apparent preference for deeper waters, and the unknown possibility that this species might occur in the PROA/St. Croix OPAREA. The distribution of unidentified rorquals (this group includes the Bryde's whale, fin whale, blue whale, minke whale, humpback whale, and sei whale, which can be difficult to distinguish from one another during some sighting conditions; Appendix Figure B-5) was also considered. It is possible that the sightings of unidentified rorquals in waters off the continental shelf (Appendix Figure B-5) could be of blue whales (Jefferson personal communication).

Behavior and Life History—Sears et al. (1990) reported that most sightings in the Gulf of St. Lawrence were of single animals or pairs, and occasionally as many as 20 to 40 animals. Blue whales, like other rorquals, feed by "gulping" (Pivorunas 1979) primarily on krill (Kenney et al. 1985). Female blue whales reach sexual maturity at 5 to 15 years of age (Yochem and Leatherwood 1985). There is usually a two-year interval between calves. Calving appears to be concentrated during the winter (Yochem and Leatherwood 1985).

The usual duration of blue whale dives is 3 to 20 min (Wynne and Schwartz 1999). Croll et al. (2001) found that blue whales dived to 140.0 (±S.D. 46.01) m and for 7.8 (±S.D. 1.89) min when foraging and to 67.6 (±S.D. 51.46) m and for 4.9 (±S.D. 2.53) min when not foraging.

Acoustics and Hearing—Blue whale emit sounds that are of an elongated low frequency vocalizations with durations up to 36 sec (Thomson and Richardson 1995). Their frequency range is 12 to 400 Hz, with dominant energy in the infrasonic range at 12 to 25 Hz (Ketten 1998). Source levels are up to 188 dB re 1 µPa-m (Ketten 1998; McDonald et al. 2001). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- Sperm Whale (*Physeter macrocephalus*)

Description—The sperm whale is the largest toothed whale species. Adult females can reach 12 m in length, while adult males measure as much as 18 m in length (Jefferson et al. 1993). The head is large (comprising about a third of the body length) and squarish (Rice 1989). The lower jaw is narrow and underslung. The blowhole is located at the front of the head and is offset to the left. Sperm whales are brownish gray to black in color with white areas around the mouth and often on the belly. The flippers are relatively short, wide, and paddle-shaped. There is a low rounded dorsal hump and a series of bumps on the dorsal ridge of the tail stock. The surface of the body behind the head tends to be wrinkled (Rice 1989).

Status—The sperm whale is listed as an endangered species under the ESA. There are no estimates of abundance for this species in the Caribbean. Stock structure for sperm whales in the North Atlantic is not known (Dufault et al. 1999). Since stock information is lacking to determine whether individuals occurring in the Caribbean are their own separate stock or part of the North Atlantic or Gulf of Mexico stocks, it is not appropriate to use abundance estimates from those areas.

Habitat Preferences—Sperm whales show a strong preference for deep waters (Rice 1989). Sperm whale distribution is associated with waters over the continental shelf break, over the continental slope, and into deeper waters (CETAP 1982; Hain et al. 1985; Kenney and Winn 1987; Waring and Finn 1995; Smith et al. 1996; Waring et al. 2001). However, in some areas, such as off New England, on the southwestern and eastern Scotian Shelf, or in the northern Gulf of California, adult males are reported to quite consistently use waters with bottom depths less than 100 m and as shallow as 40 m (Whitehead et al. 1992; Scott and Sadove 1997; Croll et al. 1999; Waring et al. 2002).

Sperm whale concentrations have been correlated with high secondary productivity and steep underwater topography (Jaquet and Whitehead 1996). Sperm whales are more frequently found in certain geographic areas, which whalers exploited (whaling "grounds" such as the Azores Islands) encompassing 300 to 1,500 square kilometers (km^2) (Townsend 1935). These main sperm whaling grounds are correlated with areas of increased primary productivity caused by upwelling (Jaquet et al. 1996). Sperm whales in the Gulf of Mexico aggregate at the mouth of the Mississippi River and along the continental slope in or near cyclonic (cold-core) eddies (Biggs et al. 2000; Davis et al. 2002). These eddies are mesoscale features with locally enhanced plankton stocks (Wormuth et al. 2000). In the eastern tropical Pacific, sperm whale habitat use is significantly related to sea surface temperature and depth of the thermocline (Polacheck 1987).

Distribution—Sperm whales are found from tropical to polar waters in all oceans of the world between approximately 70°N and 70°S (Rice 1998). Adult males are known to move into polar waters; female/immature groups rarely occur poleward of 50º (Best 1979; Rice 1989; Perry et al. 1999). Sperm whales are widely distributed in the Caribbean Sea, where they are commonly found along the continental slope and in passages between islands (Taruski and Winn 1976; Roden and Mullin 2000). Caldwell et al. (1971) and Rathjen and Sullivan (1970) reported takes of sperm whales in the whale fishery off the Lesser Antillean island of St. Vincent.

- Information Specific to PROA/St. Croix OPAREA—Globally, sperm whales are typically distributed in shelf edge waters and over the continental slope. Sperm whales are expected in the PROA/St. Croix OPAREA seaward of the continental shelf break into waters with bottom depths analogous to the open ocean (>200 m) (Figure B-7). This is based on the known habitat preferences of this species and the vast majority of sperm whale sightings in the OPAREA. Swartz et al. (2002) also reported acoustic detections of sperm whales over relatively deep waters. From this area of expected occurrence is an area of low or unknown occurrence, which is based on the few sightings that have been reported during the sparse survey effort conducted in these very deep waters (>2,000 m). In some locales, sperm whales also may be found in waters less than 100 m deep (Scott and Sadove 1997; Croll et al. 1999). To account for the possibility of encountering this species in shallow waters, there is a low or unknown sperm whale occurrence from the 30 m isobath to the shelf break (Figure B-7). This occurrence prediction is based on shallow water sperm whale sightings in the OPAREA as well as the possibility of this typically deepwater species being found in insular shelf waters that are in such close proximity to deep water. As in other areas where sperm whales are found in shelf waters, this is likely due to prey occurrence (CETAP 1982). Sperm whale occurrence patterns are assumed to be similar throughout the year.

Behavior and Life History—Sperm whales are highly social. The basic social unit is a mixed group consisting of usually 20 to 40 adult females, calves, and some juveniles (Best 1979; Rice 1989). Large male sperm whales typically occur alone or in pairs, at times joining groups of adult females for breeding. For a review of sperm whale social organization, see Whitehead and Weilgart (2000). Mating behavior is observed from winter through summer and calving during spring through fall. Gestation is 14 to 15 months, lactation is approximately 2 years, and the typical inter-birth interval is 4 to 7 years. Sperm whales prey on large mesopelagic squid and other cephalopods as well as demersal fishes and occasionally benthic invertebrates (Rice 1989; Clarke 1996). Stomach content analysis of stranded sperm whales in Puerto Rico revealed squid beaks (Mignucci-Giannoni 1996).

Sperm whales are capable of dives to depths of over 2,000 m with durations of over 60 min (Watkins et al. 1993). Average surface times between dives are less than 4 min, with 5 to 6 blows per min. Male sperm whales spend up to 83% of daylight hours under water and do not spend extensive periods of time at the surface (Jaquet et al. 2000). In contrast, females spend prolonged periods of time at the surface (1 to 5 hrs daily) without foraging (Whitehead and Weilgart 1991). The average swimming speed is estimated to be 0.7 m/sec (Watkins et al. 2002). Dive descents averaged 11 min at a rate of 1.52 m/sec, and ascents averaged 11.8 min at a rate of 1.4 m/sec (Watkins et al. 2002).

Acoustics and Hearing—Sperm whales make a variety of click sounds. These clicks range in frequency from 100 Hz to 30 kHz, with dominant energy in two bands (2 to 4 kHz and 10 to 16 kHz). Generally, most of the acoustic energy is present at frequencies below 4 kHz, although diffuse energy up to past 20 kHz has been reported (Thode et al. 2002). The source levels are 160 to 180 dB re 1 µPa-m (Thomson and Richardson 1995; Ketten 1998). Thode et al. (2002) suggested that the acoustic directivity (angular beam pattern) from sperm whales must range between 10 and 30 dB in the 5 to 20 kHz region.

Clicks are heard most frequently when sperm whales are engaged in diving/foraging behavior (Whitehead and Weilgart 1991). These may be echolocation clicks used in feeding, contact calls (for communication), or both. When sperm whales are socializing, they tend to repeat series of clicks (codas), which follow a precise rhythm and may last for hours (Watkins and Schevill 1977). Weilgart and Whitehead (1997) suggested that codas are used primarily for intragroup communication.

The anatomy of the sperm whale's ear indicates that it hears high frequency sounds (Ketten 1992). Anatomical studies also suggest that the sperm whale has some ultrasonic hearing but at a lower maximum frequency than many other odontocetes (Ketten 1992). The sperm whale may also possess better low frequency hearing than some other odontocetes, although not as extraordinarily low as many baleen whales (Ketten 1992). Auditory brainstem response in a neonatal sperm whale indicated highest sensitivity to frequencies between 5 and 20 kHz (Ridgway and Carder 2001).

- West Indian Manatee (*Trichechus manatus*)

Description—The manatee is a rotund, slow-moving animal, which reaches a maximum length of 3.9 m (Jefferson et al. 1993). The manatee has a small head, with a squarish snout with fleshy mobile lips and two semi-circular nostrils at the front. The tail is horizontal and rounded. The body is gray or gray-brown and covered with fine hairs that are sparsely distributed. The back is often covered with distinctive scars from boat propeller cuts (Moore 1956).

For many years, it was suggested that two subspecies of the West Indian manatee existed: the Florida manatee and the Antillean manatee (Domning and Hayek 1986). The Antillean manatee was considered to occur throughout the West Indies, along the Caribbean coasts of Mexico and Central America, and along the Atlantic coast of South America to central Brazil. More recent genetic analysis of the West Indian manatee is not concordant with previous subspecies designations, instead showing three distinctive lineages for this species corresponding to: (1) Florida and the West Indies, (2) the Caribbean coast and rivers of South America, and (3) the Atlantic coast of South America (Garcia-Rodriguez et al. 1998). This genetic work indicates that manatees occurring in Puerto Rico are actually of the Florida subspecies, and not the Antillean subspecies as originally suggested. More studies need to be done to clarify the stock structure of the West Indian manatee in the Caribbean.

Status—West Indian manatees are classified as endangered under the ESA. The exact number of manatees in Puerto Rico is unknown, but manatee numbers range from 43 to 101 individuals from aerial surveys conducted by the USFWS from 1984 through 1999 (Lefebvre et al. 2001). Lefebvre et al. (2001) note that the number of manatees in Puerto Rico probably has not declined and may have increased since 1978.

Rathbun et al. (1985) suggested that the principal source of human-related manatee mortality in Puerto Rico is from entanglement in gillnets. More recently, however, Mignucci-Giannoni et al. (2000) found that most human-related manatee deaths are due to watercraft collisions.

Habitat Preferences—Sightings of manatees are restricted to warm freshwater, estuarine, and extremely nearshore coastal waters. Shallow grass beds with ready access to deep channels are preferred feeding areas in coastal and riverine habitats (USFWS 2001). Manatees often use secluded canals, creeks, embayments, and lagoons, particularly near the mouths of coastal rivers and sloughs, for feeding, resting, mating, and calving (USFWS 2001). Estuarine and brackish waters and natural and artificial freshwater sources are sought by manatees (USFWS 2001).

Manatee distribution in Puerto Rico (as well as other locales where this species is found) is influenced by the availability of fresh water (Powell et al. 1981). In Puerto Rico, manatees use the Cape Hart sewage treatment plant effluent at Naval Station Roosevelt Roads (NSRR) as a source of fresh water (Powell et al. 1981; Rathbun et al. 1985). Manatees also visit the mouths of the Loíza River and Fajardo River (Powell et al. 1981). Manatees have been observed drinking fresh water that flows out of the mouth of the Río Blanco, Río Humacao, and Río Guanajibo (Lefebvre et al. 2001). Mignucci-Giannoni (1989) reported the residency of an individual manatee in the northwestern corner of Puerto Rico where manatees are not frequently observed but was able to determine from local divers that a submarine freshwater stream occurs there.

Seagrass beds are relatively sparse along the northwest coast of Puerto Rico where manatees are infrequently seen. Deep waters close to shore and a lack of embayments also result in less favorable habitat along the north coast (Powell et al. 1981; Lefebvre et al. 2001). Seagrass beds are extensive on the eastern and southern coasts of the island. Tagging studies reveal a heavy reliance on the seagrass beds and nearshore waters of NSRR (Lefebvre et al. 2000). Areas of high manatee use are concentrated in the main harbor at NSRR, and in other locations, shallow coves and bays protected from wave action. In the area of NSRR, manatees have been sighted feeding in Pelican Cove and Ensenada Honda (Rathbun et al. 1985; Freeman and Quintero 1990; Lefebvre et al. 2000). There is high use of seagrass beds by manatees in Bahía Algodones, west of Roosevelt Roads (Reid 1994). Kruer (1995) and Reid et al. (2001) have characterized seagrass habitat to establish baseline conditions and document the effects of various impacts on seagrasses, including manatees foraging on them.

Reid and Kruer (1998) mapped and characterized the nearshore benthic habitat around Vieques Island. The higher incidence of manatees (in particular, cow/calf pairs) observed at NSRR and northwestern Vieques Island is related to the abundance of seagrass beds (Rathbun et al. 1985; Reid and Kruer 1998; Lefebvre et al. 2000). It should be noted, however, that although seagrass beds extend several kilometers offshore and are found in waters with bottom depths greater than 20 m, most observations of feeding manatees are close to shore and in shallow water (range 1 to 5 m) (Lefebvre et al. 2000). Even though seagrass biomass appears to be higher in Vieques than NSRR, the habitat of Vieques may not be as attractive to manatees with freshwater sources difficult to locate (Diaz et al. 1992).

Distribution—West Indian manatees occur in warm, subtropical, and tropical waters of the western North Atlantic from the southeastern U.S. to Central America, northern South America, and the West Indies, primarily in freshwater systems, estuaries, and shallow, nearshore, coastal waters (Lefebvre et al. 2001).

Manatees in Puerto Rico are found in coastal waters, well inside the continental shelf and, rarely, if at all, near the shelf edge (Mignucci-Giannoni 1989). Mignucci-Giannoni (1989) did note that manatee distribution is probably an indirect one, reflecting the topography and substrate requirements for seagrasses. Aerial surveys document the greatest manatee concentrations along the south-central and eastern shores of Puerto Rico and none on the northwestern shore (Powell et al. 1981; Rathbun et al. 1985; Lefebvre et al. 2001). Slightly over one-third of sightings at Puerto Rico are around NSRR on the eastern end of the island in the area of Fajardo and Ceiba, and the northwestern shore of nearby Vieques Island (Powell et al. 1981; Rathbun et al. 1985). Along the south coast, they are common in the Jobos Bay area between Guayama and Salinas (Mignucci-Giannoni et al. 2002). Tagging data have shown high use of the southwest coast (Mayaguez to Boqueron) (Mignucci-Giannoni et al. 1999b). One tagged subadult male moved from Mayaguez (Puerto Rico's west coast) to San Juan and Luquillo (northeast coast), for a distance of 210 km (Mignucci-Giannoni et al. 1999b). Manatees are infrequently seen in areas immediately to the west of San Juan (Mignucci-Giannoni 1989). Alsina-Guerrero et al. (2001) noted a decline in manatee sightings in San Juan Bay, but were not able to speculate on the cause.

Satellite and radio-tracking data have shown that there are manatees making directed long-distance movements between eastern Puerto Rico and Vieques (Reid and Bonde 1993; Reid and Kruer 1998;

Lefebvre et al. 2000). The area on the northwest coast of Vieques Island, to the west of Mosquito Pier, is well-known to be used for feeding and resting by manatees (Magor 1979; Rathbun et al. 1985; Reid and Kruer 1998). The width of the seagrass bed (mixed *Thalassia* and *Syringodium*) on the northwest end of Vieques is greater than that of any other grass bed on Vieques (Magor 1979). Magor (1979) noted that sightings were concentrated in the lee of Mosquito Peer and off the mouth of Kiani Lagoon on Vieques. Manatees also use areas along the southern shore of Vieques (Reid 1994; GMI unpublished data).

As noted by Lefebvre et al. (2001), except for Vieques Island, manatees are rarely reported from the islands offshore of Puerto Rico. There is a stranding documented from St. Thomas; there are rare sightings of manatees in the Virgin Islands (Mignucci-Giannoni 1989; Mignucci-Giannoni 1996; Lefebvre et al. 2001). A manatee was entangled in a fishing net off Culebra Island in 1982 and one was reported there in 1999 (Mignucci-Giannoni 1989; Lefebvre et al. 2001). There are now only fossil records of manatees occurring in the Virgin Islands, Antigua, Martinique, and St. Lucia (Rathbun and Possardt 1986; Mignucci-Giannoni 1989).

- Information Specific to PROA/St. Croix OPAREA—The West Indian manatee is expected to occur in the coastal waters of most of Puerto Rico, all of Culebra, and around most of Vieques (Figure B-8). Occurrence patterns are expected to be the same throughout the year. Occurrence was determined by using location information from survey and opportunistic sightings (Figure B-8), tagging efforts by the Sirenia Project (Reid 1994, 1995, 1996, 1997; Mignucci-Giannoni et al. 1999b), and habitat preferences of this species (e.g., Magor 1979; Rathbun et al. 1985; Lefebvre et al. 2000). Habitat preferences considered included the presence of shallow seagrass beds (NOS 2001), availability of freshwater sources (including river mouths and effluents), shallow waters, and embayments where manatees are protected from strong wave action. Manatees as a result are expected to occur (most often in a concentrated fashion) in waters close to the shoreline of Puerto Rico with the exception of the northwest shore. The south shore has access to seagrass beds and fresh water, as does the east side of the island, particularly in the area of NSRR NOS 2001; Reid et al. 2001). The west side of Puerto Rico offers embayments that could protect manatees from wave surges, as well as seagrasses. Occurrence is expected around the entire island of Culebra, even though there have been few reported sightings around Culebra. Culebra has seagrass beds that should be attractive to manatees for foraging purposes (NOS 2001). Occurrence is also expected (and concentrated) around most of Vieques, based on sightings from surveys (Appendix Figure B-8), tagging information from the Sirenia Project (e.g., Reid 1997), and an extensive seagrass bed on the northwest corner of Vieques (Magor 1979; Reid and Kruer 1998; NOS 2001).

  There is a low or unknown occurrence of manatees on the northwest and north-central shore of Puerto Rico. This is based on the low number of sightings in this area, which are likely a reflection of habitat that is not favorable for manatees to frequent for any extended period of time. Deep waters come very close to shore on the north side of Puerto Rico, there is no seagrass habitat (or very little) in this area, and manatees would be exposed to rough water conditions (NOS 2001). There is a low or unknown occurrence of manatees in the waters connecting Puerto Rico and Culebra, Puerto Rico and Vieques, close to shore around St. Croix, USVI, and in the waters around the rest of the Virgin Islands. This is based on the few sightings that have been made in those areas and the possibility that encountering the highly endangered manatee may occur.

Behavior and Life History—Two important aspects of the manatee's physiology influence behavior: nutrition and metabolism. Manatees have an unusually low metabolic rate and a high thermal conductance that leads to energetic stress in winter, ameliorated by migration and aggregation in warm-water refugia (Hartman 1979). Manatees are herbivores that feed opportunistically on a wide variety of submerged, floating, and emergent vegetation (USFWS 2001). The diet of the manatee in Puerto Rico appears to consist of turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*), with occasional use of mangrove and accidental ingestion of green alga (sea lettuce [*Ulva lactuca*] and grass caulerpa [*Caulerpa prolifera*]) and hydroids (Mignucci-Giannoni and Beck 1998). Manatees in Puerto Rico often fed on turtle grass due to its

abundance. However, manatees exhibit selective feeding by returning to specific sites with abundant shoal grass (Lefebvre et al. 2000). Manatees also appear to feed selectively on turtle grass shoots associated with clumps of the calcareous alga called halimeda macroalgae (*Halimeda opuntia*) (Lefebvre et al. 2000). Manatees in Florida have not demonstrated this specialized feeding behavior.

Manatees are most often observed singly (Hartman 1979; Mignucci-Giannoni 1989); they are not very social. Manatees in Florida aggregate in large numbers around warm water sources (Hartman 1979). Calves are probably born year-round (Hartman 1979; Mignucci-Giannoni 1989).

Acoustics and Hearing—Manatees produce pulsed 200 to 500 ms species-specific calls (Gerstein et al. 2001). The average frequency range is between 1,000 and 12,000 Hz (Steel and Morris 1982). Ketten et al. (1992) described the anatomy of the manatee ear. Audiogram work suggests that manatees may hear better than originally suggested (Gerstein 1999; Gerstein et al. 1999; Gerstein 2002). Manatees have high frequency sensitivity, narrow critical bands, and pulsed broadband calls (Gerstein et al. 1999). Current behavioral data for the West Indian manatee indicate a hearing range of approximately 0.4 to 46 kHz, with best sensitivities between 16 and 18 kHz (50 dB re 1 µPa-m). The range of best hearing is 6 to 20 kHz.

3.1.2.2 Non-Threatened and Non-Endangered Marine Mammal Species of PROA/St. Croix OPAREA

There are 25 non-endangered/non-threatened marine mammal species: two baleen whale species and 23 toothed whale species. For many of the marine mammal species occurring in the PROA/St. Croix OPAREA, there are multiple records for their occurrence; for some, there may be just one record. For species with few records, this may be a result of difficulty in species identification or extralimital occurrences of the species. Any sightings of hooded seals in the PROA/St. Croix OPAREA represent uncommon extralimital occurrences of individuals that strayed from their normal distribution.

- Minke Whale (*Balaenoptera acutorostrata*)

Description—The minke whale is the smallest rorqual species in the western North Atlantic, with adults reaching lengths of just over 9 m (Jefferson et al. 1993). The head is extremely pointed, and the median head ridge is prominent. The dorsal fin is tall, recurved, and is located about two-thirds of the way back from the snout tip (Jefferson et al. 1993). The minke whale's coloration is distinct: dark gray dorsally, white beneath, and streaks of intermediate shades on the sides (Jefferson et al. 1993). The most distinctive light marking is a brilliant white band across each flipper of northern hemisphere minke whales (Stewart and Leatherwood 1985).

Status—In the North Atlantic, there are four recognized populations–Canadian east coast, west Greenland, central North Atlantic, and northeastern North Atlantic (Waring et al. 2002). Minke whales off the eastern U.S. are considered to be part of the Canadian east coast stock, which inhabits the area from the eastern half of the Davis Strait out to 45ºW and south to the Gulf of Mexico (Waring et al. 2002). The best available current abundance estimate for the Canadian east coast stock of minke whales is 4,018 individuals (Waring et al. 2002). There is no stock information for minke whales that are sighted in the Caribbean. There are no abundance estimates for this species for the Puerto Rico area.

Habitat Preferences—Off eastern North America, the minke whale generally occupies waters over the continental shelf, including inshore bays and estuaries (Waring and Palka 2002; Waring et al. 2002). However, based on whaling catches and surveys worldwide, there is a deep-ocean component to the minke whale's distribution (Slijper et al. 1964; CETAP 1982; Horwood 1990; Mitchell 1991; Mellinger et al. 2000; Waring et al. 2002).

Distribution—Minke whales are distributed in polar, temperate, and tropical waters (Jefferson et al. 1993). There appears to be a strong seasonal component to minke whale distribution. Spring and summer are times of relatively widespread and common occurrence, and during this time, they are most abundant in New England waters (Waring et al. 2002). During fall in New England waters, there

are fewer minke whales; during winter the species appears to be largely absent. Minke whales are known to occur during the winter months (November through March) in the southwestern region of the North Atlantic including the area from Bermuda to the West Indies (Mitchell 1991).

Most minke whale sightings in the Caribbean have been in January and February, though minke whales have been reported as early as December (Winn and Perkins 1976) and as late as May (Mignucci-Giannoni 1998). Mignucci-Giannoni (1998) found minke whales distributed equally over the continental shelf and near the shelf break and less frequently offshore. However, Roden and Mullin (2000) reported sighting three minke whales during winter 1995, in waters 5,490 m deep, about 160 km northeast of Puerto Rico. Mellinger et al. (2000) recorded pulse trains that they attributed to minke whales in an area 190 to 350 km northeast of Puerto Rico during March 1994.

- Information Specific to PROA/St. Croix OPAREA—Minke whales are known to occur during the winter months in the West Indies (Mitchell 1991). Appendix Figure B-9 shows that there are sightings in both winter and spring, which may reflect some differences in migration patterns, with some individuals leaving later than others. Clark (1995) detected minke whales (by passive acoustic means) in the southern part of the western North Atlantic during the fall, winter, and spring. Despite the lack of sightings of minke whales in the OPAREA at other times of the year, it is assumed that minke whales have a similar life history as the other rorquals with a population shift north into summer feeding grounds.

  The winter range of some rorquals (and often extrapolated to the minke whale) is thought to be in deep, offshore waters particularly at lower latitudes (Kellogg 1928; Gaskin 1982). Minke whale sightings have been reported in deep waters during this time of year (Slijper et al. 1964; Mitchell 1991).

  During winter, spring, and fall, there is a low or unknown occurrence of minke whales from the shore to past the boundaries of the PROA/St. Croix OPAREA. This takes into consideration both sightings in shallow waters, as well as the anticipated oceanic occurrence (Appendix Figure B-9).

Behavior and Life History—Minke whales are sighted in small groups. Mating is thought to occur in winter or early spring, but has never been observed (Stewart and Leatherwood 1985). Stern (1992) described a general surfacing pattern of minke whales consisting of about four surfacings, interspersed by short-duration dives averaging 38 sec. After the fourth surfacing, there was a longer duration dive ranging from approximately 2 to 6 min. Minke whales are “gulpers” like the other rorquals (Pivorunas 1979). Hoelzel et al. (1989) reported on different feeding strategies used by minke whales. In the western North Atlantic, minke whales feed primarily on schooling fish such as sand lance, capelin, herring, and mackerel (Kenney et al. 1985).

Acoustics and Hearing—Recordings in the presence of minke whales have included both high- and low-frequency sounds (Beamish and Mitchell 1973; Winn and Perkins 1976; Mellinger et al. 2000). Mellinger et al. (2000) described two basic forms of pulse trains that were attributed to minke whales: a “speed up” pulse train with energy in the 200 to 400 Hz band, with individual pulses lasting 40 to 60 msec, and a less-common “slow-down” pulse train characterized by a decelerating series of pulses with energy in the 250 to 350 Hz band. Recorded vocalizations from minke whales have dominant frequencies of 60 to greater than 12,000 Hz, depending on vocalization type (Thomson and Richardson 1995). Recorded source levels, depending on vocalization type, range from 151 to 175 dB re 1 µPa-m (Ketten 1998). Gedamke et al. (2001) recorded a complex and stereotyped sound sequence that spanned a frequency range of 50 Hz to 9.4 kHz. Broadband source levels between 150 and 165 dB re 1 µPa-m were calculated. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- Bryde’s Whale (*Balaenoptera edeni*)

Description—Bryde’s whales can be easily confused with sei whales. Bryde’s whales usually have three prominent ridges on the rostrum (other rorquals generally have only one) (Jefferson et al. 1993).

The Bryde's whale's dorsal fin is tall and falcate and generally rises abruptly out of the back. Adults can be up to 15.5 m in length (Jefferson et al. 1993).

It is not clear how many species of Bryde's whales there are, but genetic analyses suggest the existence of two species (Rice 1998; Kato 2002).

Status—There is no abundance information available for the Bryde's whale in the Caribbean or off the continental U.S.

Habitat Preferences—Bryde's whales are found both offshore and near the coasts in many regions. Off Venezuela, Bryde's whales are often sighted in the shallow waters between Isla Margarita and Peninsula de Araya, as well as into waters where there is a steep slope, such as the Cariaco Trench (Notarbartolo di Sciara 1982). In the Gulf of Mexico, all Bryde's whale sightings have been near the shelf break in Desoto Canyon (Jefferson and Schiro 1997).

Distribution—The Bryde's whale is found in tropical and subtropical waters, generally not moving poleward of 40º in either hemisphere (Jefferson et al. 1993). Cummings (1985) reported that Bryde's whales are seen in the Caribbean southward to Brazil. Debrot et al. (1998) noted that the Bryde's whale is the most common rorqual in the southeastern Caribbean. There is only one record for Bryde's whale for Puerto Rico and the Virgin Islands, a live stranding occurring on St. Croix, USVI in 1991 (Mignucci-Giannoni 1996).

- Information Specific to PROA/St. Croix OPAREA—Bryde's whales are seen year-round throughout tropical and subtropical waters (Kato 2002). There is a known concentrated occurrence of this species in Venezuelan waters (Notarbartolo di Sciara 1982). There are occasional reported sightings of this species in the rest of the Caribbean. The Bryde's whale has been reported to occur in both deep and shallow waters globally. While the Bryde's whale could be found in shallow waters, it is not expected to occur up to the shoreline. Therefore, the Bryde's whale has a low or unknown occurrence from the 30 m isobath to seaward of the PROA/St. Croix OPAREA boundaries (Figure B-10). Bryde's whale occurrence patterns are assumed to be the same throughout the year. The distribution of unidentified rorquals (Figure B-5) was also considered to predict the Bryde's whale occurrences. It would be reasonable to assume that some of the sightings that were recorded as unidentified rorquals (the Bryde's whale, fin whale, blue whale, minke whale, humpback whale, and sei whale, which can be difficult to distinguish from one another during some sighting conditions) might be of Bryde's whales. It is likely that the sightings in waters on the continental shelf or very near the shelf break (Figure B-5) are of Bryde's whales (Jefferson personal communication).

Behavior and Life History—This species is generally seen alone or in pairs (Tershy 1992). The Bryde's whale does not have a well-defined breeding season in most areas. There is a 2-year reproductive cycle composed of 11 to 12 months of gestation, 6 months of lactation, and 6 months of resting (Kato 2002). Bryde's whales are lunge-feeders, feeding primarily on fish, but they also take small crustaceans. Cummings (1985) reports that Bryde's whales may dive as long as 20 min.

Acoustics and Hearing—Bryde's whales produce very low frequency tonal and pulsed moans similar to other rorquals (Oleson et al. 2001). All Bryde's whale sounds recorded have been low-frequency pulsed and non-pulsed moans in the 100 to 900 Hz range that do not occur in long, patterned sequences (Edds et al. 1993). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- Pygmy and Dwarf Sperm Whales (*Kogia breviceps* and *Kogia sima*, respectively)

Description—Pygmy sperm whales have a shark-like head with a narrow underslung lower jaw (Jefferson et al. 1993). The flippers are set high on the sides near the head. The small falcate dorsal fin of the pygmy sperm whale is usually set well behind the midpoint of the back (Jefferson et al. 1993). The dwarf sperm whale is similar in appearance to the pygmy sperm whale, but the dwarf

sperm whale has a larger dorsal fin, generally set nearer the middle of the back (Jefferson et al. 1993). The dwarf sperm whale also has a shark-like profile but with a more pointed snout than the pygmy sperm whale. Pygmy and dwarf sperm whales reach body lengths of around 3.0 m and 2.5 m, respectively (Plön and Bernard 1999).

Dwarf and pygmy sperm whales are difficult to distinguish from one another at sea, and sightings of either species are often categorized as *Kogia* spp. The difficulty in identifying pygmy and dwarf sperm whales is exacerbated by their avoidance reaction towards ships and change in behavior towards approaching survey aircraft (Würsig et al. 1998). Based on the cryptic behavior of these species and small group sizes (much like that of beaked whales), as well as similarity in appearance, it is difficult to identify *Kogia* to species. This is evident in that all the sightings of *Kogia* spp. do not have a species identity determined (Figure B-11).

Status—There are no abundance estimates for this species in the Caribbean. Fisheries interactions have played a prominent role in mortality for *Kogia* off Puerto Rico.

Habitat Preferences—Both species of *Kogia* generally occur in waters along the continental shelf break and over the continental slope (McAlpine 2002). Data from the Gulf of Mexico suggest that *Kogia* may associate with frontal regions along the shelf break and upper continental slope, areas with high epipelagic zooplankton biomass (Baumgartner et al. 2001). The zooplankton is likely part of the diet of one or more of the common prey species of *Kogia*. A satellite-tagged, rehabilitated pygmy sperm whale released off the Atlantic coast of Florida remained along the continental slope and the western edge of the Gulf Stream during the time of the tag's operation (Scott et al. 2001). Dwarf sperm whales may have a more oceanic distribution than pygmy sperm whales and/or dive deeper during feeding bouts, based on hematological and stable-isotope data (Barros et al. 1998).

Distribution—Both *Kogia* species have a worldwide distribution in tropical and temperate waters (Jefferson et al. 1993). Cardona-Maldonado and Mignucci-Giannoni (1999) reviewed information on *Kogia* spp. in Puerto Rico and the Virgin Islands and suggested that they are resident in the Caribbean.

- Information Specific to PROA/St. Croix OPAREA—Sighting and stranding data are also included for *Kogia* spp, which were not identified as either the pygmy sperm whale or the dwarf sperm whale. As noted earlier, identification to species for this genus is difficult, particularly at sea. Sightings that were listed as unidentified *Kogia* spp. were plotted as such. When a *Kogia* species was identified to species, pygmy sperm whale or dwarf sperm whale was plotted accordingly.

  There are few recorded sightings within the PROA/St. Croix OPAREA (Figure B-11). As noted by Cardona-Maldonado and Mignucci-Giannoni (1999), more survey effort in conjunction with continued monitoring of stranding events should yield additional records of *Kogia* spp. and much needed information on the distribution and habitat preferences of these species. Based on the little available information for these two species in this OPAREA and the known preference of these two species for deep waters, there is a low or unknown occurrence from the vicinity of the continental shelf break to beyond the boundaries of the OPAREA (Figure B-11). Occurrence patterns are assumed to be the same for all four seasons.

Behavior and Life History—*Kogia* have small group sizes (mean group size is usually two individuals) (Willis and Baird 1998). A recent study of *Kogia* in South Africa has determined that these two species have a much earlier sexual maturity and shorter life span than other similarly sized toothed whales (Plön and Bernard 1999). Sexual maturity is attained at around 4 years in both sexes of both species. *Kogia* feed on cephalopods and, less often, on deep-sea fishes and shrimps (Caldwell and Caldwell 1989; Baird et al. 1996; Willis and Baird 1998). Stomach contents from stranded *Kogia* in Puerto Rico and the Virgin Islands included small squid beaks, a deepwater, small shrimp-like crustacean (mysid), and small fish probably related to deepwater searobins (Family Triglidae) (Cardona-Maldonado and Mignucci-Giannoni 1999). Willis and Baird (1998) reported that *Kogia* make dives of up to 25 min. A satellite-tagged pygmy sperm whale released off FL was found

to make long nighttime dives, presumably indicating foraging on squid in the deep scattering layer (Scott et al. 2001). Most sightings of *Kogia* are brief; these whales are often difficult to approach and actively avoid aircraft and vessels (Würsig et al. 1998).

Acoustics and Hearing—Pygmy sperm whale clicks range from 60 to 200 kHz, with a dominant frequency of 120 kHz (Thomson and Richardson 1995). There is no information available on dwarf sperm whale vocalizations. An auditory brainstem response study indicates that pygmy sperm whales have their best hearing between 90 and 150 kHz (Ridgway and Carder 2001).

- Beaked Whales (Family Ziphiidae)

Description—There are six species of beaked whales known to occur in the western North Atlantic Ocean; five may occur in the PROA/St. Croix OPAREA. While there are confirmed records for the Cuvier's beaked whale (*Ziphius cavirostris*), Gervais' beaked whale (*Mesoplodon europaeus*), and Blainville's beaked whale (*M. densirostris*), it is possible for True's and Sowerby's beaked whales (*M. mirus* and *M. bidens*, respectively) to make an appearance here. Of these species, only the Cuvier's beaked whale is relatively easy to identify (Coles 2001). The head and back of Cuvier's beaked whale may be extensively light gray or white, in contrast to the darker coloration of the other beaked whale species (Jefferson et al. 1993).

Morphological and coloration similarities among species in the genus *Mesoplodon* make identification of free-ranging animals difficult. Coles (2001) provided a description of features that may aid in positive identification at sea. Coloration is usually brownish gray to olive with white scarring and spots. *Mesoplodon* species are small whales with maximum reported adult lengths of 6.2 m (Mead 1989). They have a relatively small head, large thorax and abdomen, and short tail. *Mesoplodon* species all have a pair of throat grooves on the ventral side of the head between the lower jaws. Beaked whales in the genus *Mesoplodon* are characterized by the presence of a single pair of sexually dimorphic tusks, which erupt only in adult males. MacLeod (2000a) suggested that the variation in the position and shape of the tusks acts as a species recognition character for these whales. Gervais' beaked whale males reach lengths of at least 4.5 m, while females reach at least 5.2 m (Jefferson et al. 1993). Blainville's beaked whales appear to reach a maximum of around 4.7 m (Jefferson et al. 1993).

Cuvier's beaked whales are relatively robust compared to other beaked whale species. Male and female Cuvier's beaked whales may reach 7.5 and 7.0 m in length, respectively (Jefferson et al. 1993). This species has a relatively short beak, which, with the curved jaw, resembles a goose beak.

Status—There are no estimates of abundance for any beaked whale species in the Caribbean.

Habitat Preferences—Little is known about the habitat preferences of beaked whales. Beaked whale abundance off the eastern U.S. may be highest in association with the Gulf Stream and associated warm-core rings (Waring et al. 1992). In summer, beaked whales use the shelf edge region off the northeast U.S. as primary habitat (Waring et al. 2001). Ferguson et al. (2001) noted that offshore waters beyond the continental slope are not often identified as beaked whale habitat, yet this may be a function of lack of survey effort rather than a reflection of the animals' true habitat.

A Blainville's beaked whale population in the Bahamas was found to spend the majority of their time in waters with bottom depths of 200 m to 1,000 m (with gully-like physiographic features), with a possible preference for waters deeper than 500 m (MacLeod and Claridge 1999). MacLeod and Claridge (1999) also noted that local scale distribution in the Bahamas might be limited to small areas of suitable habitat, particularly for foraging.

Distribution—Beaked whales normally inhabit deep ocean waters (>2000 m) or continental slopes (200 to 2000 m), and only rarely stray over the continental shelf (Pitman 2002). The distribution of *Mesoplodon* species in the western North Atlantic is known almost entirely from strandings (Mead 1989; MacLeod 2000b).

The Cuvier's beaked whale is the most cosmopolitan of all beaked whale species, occurring in most oceans. The Cuvier's beaked whale is the second most common species stranded in Puerto Rico and the U.S. Virgin Islands (Mignucci-Giannoni 1989); mass strandings of this species are also known for this area. The ranges of many beaked whales of the genus *Mesoplodon* are poorly known. Distribution of Mesoplodon in the North Atlantic may relate to water temperature (MacLeod 2000b). Blainville's beaked whale and Gervais' beaked whale occur in warmer southern waters (MacLeod 2000b). There are stranding records for both of these beaked whale species in the northeastern Caribbean (Rosario-Delestre et al. 1999). There may be species other than Blainville's, Cuvier's, and Sowerby's beaked whales (species represented by confirmed records) occurring in this area. For example, the True's beaked whale is known from the nearby Bahamas and the east coast of Florida (Mead 1989; MacLeod 2000b). The True's beaked whale could regularly occur off Puerto Rico, particularly considering how little is known about beaked whale distribution (Jefferson personal communication). This in contrast to the suggestion by Rosario-Delestre et al. (1999) that any sightings of True's beaked whales off Puerto Rico would be extralimital. There is one stranding record for the Sowerby's beaked whale in the Gulf of Mexico (Jefferson and Schiro 1997). Sowerby's beaked whale is considered a temperate water species, so it is not expected in this area (Jefferson personal communication). Any records of the Sowerby's beaked whale in the Caribbean would likely be considered extralimital (Jefferson and Schiro 1997).

- Information Specific to PROA/St. Croix OPAREA—Beaked whales may be expected to occur in the area near the continental shelf break into waters seaward of where the bottom topography becomes steep and then flat (Figure B-12). There is a low or unknown occurrence of this species past the area of expected occurrence, which takes into account the possibility of encountering this species (as evidenced by a sighting in the southern portion of the OPAREA during winter and the low dedicated survey effort in this area). There is a low or unknown occurrence of beaked whales on the continental shelf, and is based on the number of sightings on the continental shelf, which may be a reflection of the fact that deep waters come close to the shore in this OPAREA. Beaked whale occurrence patterns are assumed to be the same throughout the year. Because of the behavior of these species and similarity in appearance, it is difficult to identify beaked whales to species, particularly at sea. This is evident in the number of sightings of unidentified beaked whales in contrast to those where the species identity was determined (Figure B-12).

Behavior and Life History—Observed group sizes of beaked whales are small (1 to 4 individuals). Most sightings are brief; these whales are often difficult to approach and actively avoid aircraft and vessels (Würsig et al. 1998). Life history data on beaked whales species are extremely limited. Seasonality of calving is not known for beaked whale species.

All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (MacLeod 2001). Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction predominantly on mesopelagic fish and squid or deepwater benthic invertebrates (Heyning 1989; Mead 1989; Heyning and Mead 1996; Santos et al. 2001). Stomach content analysis of Cuvier's and Gervais' beaked whales off Puerto Rico revealed deepwater shrimp (*Gnathophausia* spp.) (Mignucci-Giannoni 1996). *Mesoplodon* species occupy a separate ecological niche (feeding on smaller cephalopods) from the Cuvier's beaked whale, which allows *Mesoplodon* species to locally co-exist with the Cuvier's beaked whale (MacLeod 2001). Gannon et al. (1998) hypothesized that earlier reports overestimated the importance of squids in the diet of two beaked whale species, since squid beaks are more resistant to digestion than fish otoliths. Dives exceeding 45 min have been documented for Cuvier's and Blainville's beaked whales (Jefferson et al. 1993). Durations of long dives for *Mesoplodon* spp. are over 20 min (Barlow 1999).

Acoustics and Hearing—Very little information is available on characteristics of sound produced by beaked whales. MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Caldwell and Caldwell (1971) recorded short whistles/chirps from a live, stranded Blainville's beaked whale; the frequency range was 1 to 6 kHz. Click pulses of Cuvier's beaked

whales recorded by Frantzis et al. (2002) had a frequency peak between 13 and 17 kHz. No data are available on the hearing range of beaked whales. Slow and fast clicks and "a narrow band sound" were recorded from a stranded Gervais' beaked whale (Norman and Mead 2001). There is no direct information available on the exact hearing abilities of beaked whales (MacLeod 1999). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no evidence to support this idea (MacLeod 1999).

- Rough-toothed Dolphin (*Steno bredanensis*)

Description—This is a relatively robust dolphin with a cone-shaped head and no demarcation between the melon and beak (Jefferson et al. 1993). The rough-toothed dolphin has large flippers that are set far back on the side and a prominent falcate dorsal fin (Jefferson et al. 1993) The body is dark gray, with a prominent narrow dorsal cape that dips slightly down onto the side below the dorsal fin. The lips and much of the lower jaw are white. The rough-toothed dolphin reaches 2.8 m in length (Jefferson et al. 1993).

Status—There are no abundance estimates available for the rough-toothed dolphin in the Caribbean.

Habitat Preferences—The rough-toothed dolphin is found in deep, offshore waters. In the Gulf of Mexico, the rough-toothed dolphin occurs primarily over the deeper waters (bottom depths of 950 to 1,100 m) off the continental shelf (Davis et al. 1998). However, Mignucci-Giannoni (1989, 1998) reported that all records for this species for Puerto Rico and the Virgin Islands are in waters over the continental shelf. Lodi and Hetzel (1999) reported that rough-toothed dolphins were found on the continental shelf in Ilha Grande Bay (southeastern coast of Brazil), but there has not been much sighting effort in deep waters.

Distribution—Rough-toothed dolphins are found in tropical to warm-temperate waters globally (Miyazaki and Perrin 1994). In most areas where they are known to occur, they are not commonly encountered (Jefferson 2002a). There are not many records for this species from the western North Atlantic (Leatherwood et al. 1976). The rough-toothed dolphin was infrequently captured in the St. Vincent small cetacean fishery in the Lesser Antilles (Caldwell et al. 1971).

- Information Specific to PROA/St. Croix OPAREA—Winter is the only season with sighting records for the rough-toothed dolphin in the PROA/St. Croix OPAREA (Figure B-13). It is possible that the lack of sightings in other seasons might reflect the possibility of some rough-toothed dolphins being misidentified as bottlenose dolphins, a species they closely resemble (Jefferson personal communication). Occurrence of rough-toothed dolphins throughout the year is expected from the shelf break to the 3,000 m isobath both north and south of Puerto Rico and the Virgin Islands, following the outline of the Antilles Island Arch (Figure B-13). This is a species known to prefer deep waters. The rough-toothed dolphin is a tropical species and is expected to occur in the area year-round. Information on rough-toothed dolphin occurrence in other areas of the world suggests that there should be no significant seasonality in their distribution patterns (Jefferson personal communication). There is a low or unknown occurrence of rough-toothed dolphins on the continental shelf based on the sightings occurring there, and also the fact that there are only a few sightings, all occurring during one season, making it difficult to ascertain whether this species should be expected to occur on the shelf at all in this area.

Behavior and Life History—Small groups of 10 to 20 rough-toothed dolphins are most common, with herds up to 50 animals reported (Miyazaki and Perrin 1994). Mignucci-Giannoni (1998) reported groups of 3 to 30 individuals. This species is known to mass strand (Rhinehart et al. 1999). Female rough-toothed dolphins tend to reach sexual maturity between 4 and 6 years of age; males attain sexual maturity between 5 and 10 years of age (Mead et al. 2001). Rough-toothed dolphins may stay submerged for up to 15 min and are known to dive as deep as 70 m, but can probably dive much deeper (Miyazaki and Perrin 1994). This species often associates with other small cetaceans. Off

Puerto Rico and the Virgin Islands, rough-toothed dolphins have been sighted in association with humpback whales (Mignucci-Giannoni 1998). At least in the eastern tropical Pacific, rough-toothed dolphins tend to associate with floating objects (Jefferson personal communication). Cephalopods and fish, including large fish such as dorado, are prey (Jefferson et al. 1993; Miyazaki and Perrin 1994).

Acoustics and Hearing—Echolocation clicks of rough-toothed dolphins are in the frequency range of 0.1 to 200 kHz, with a peak of about 25 kHz; whistles have a maximum energy of 2 to 14 kHz (Miyazaki and Perrin 1994). There is no information on hearing ability of this species.

- Common Bottlenose Dolphin (*Tursiops truncatus*)

Description—Bottlenose dolphins (genus *Tursiops*) are large, relatively robust dolphins that vary in color from light gray to charcoal. *Tursiops* is named for its short, stocky snout that is distinctively set off from the melon by a crease (Jefferson et al. 1993). There is striking regional variation in body size; adult body length ranges from 1.9 to 3.8 m (Jefferson et al. 1993).

The taxonomy of the bottlenose dolphin continues to be in flux. Two species of *Tursiops* are currently recognized, the common bottlenose dolphin and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) (Rice 1998; IWC 2001), with more likely to be recognized with more genetic analyses. The Indo-Pacific bottlenose dolphin is found in the tropical Indo-Pacific, while all other bottlenose dolphins including those found in the western North Atlantic are considered to be the common bottlenose dolphin. Hereafter, the bottlenose dolphin refers to the common bottlenose dolphin. Scientists currently recognize a nearshore (coastal) and an offshore form of the bottlenose dolphin, which may be distinguished by external morphology, hematology, cranial morphology, diet, and parasite load (Duffield et al. 1983; Hersh and Duffield 1990; Mead and Potter 1995). There is a clear genetic distinction between the nearshore and offshore form of the bottlenose dolphin in the western North Atlantic (Curry and Smith 1997; Hoelzel et al. 1998; Rosel and Bero 2001).

Status—There are no abundance estimates for this species for the Caribbean. An estimated 314 bottlenose dolphins use the southwest coast of Puerto Rico (Rodríguez Ferrer 2001). There is no information available on stock differentiation for this area.

Habitat Preferences—Bottlenose dolphins in the northeastern Caribbean are reported to occur most often in waters over the continental shelf (Mignucci-Giannoni 1998). Sightings have been also recorded in offshore waters of this area (Mignucci-Giannoni 1998; Roden and Mullin 2000; Rodriguez Ferrer 2001). Coastal and offshore forms are known to occur off the U.S. Atlantic coast and in the northern Gulf of Mexico (Waring et al. 2002). No studies have been conducted on whether there are two forms of this species in the Caribbean; however, one individual found stranded in Puerto Rico was determined to be of the offshore form (Rosel personal communication).

Distribution—The overall range of *Tursiops* is worldwide in tropical and temperate waters. *Tursiops* generally do not range poleward of 45º, except around the United Kingdom and northern Europe (Jefferson et al. 1993). Climate changes can contribute to range extensions. For example, a 600 km northward range extension to Monterey Bay (for some bottlenose dolphins known to the San Diego, California, area) was linked to the 1982 to 1983 El Niño event (Wells et al. 1990). Bottlenose dolphins continue to occur in Monterey Bay.

There are numerous opportunistic records of bottlenose dolphins for the northeastern Caribbean, including Puerto Rico, the Virgin Islands, and Culebra (Erdman et al. 1973; Mignucci-Giannoni 1989; Mignucci-Giannoni 1998). However, only one systematic study of bottlenose dolphins has been conducted around Puerto Rico (Rodríguez Ferrer 2001). The bottlenose dolphin is common year-round in Puerto Rican waters (Mignucci-Giannoni 1989, 1998), with peak occurrence during the fall (Rodríguez Ferrer 2001).

- Information Specific to PROA/St. Croix OPAREA—Bottlenose dolphins are expected from the coast to the 3,000 m isobath both north and south of Puerto Rico and the Virgin Islands, following the outline of the Antilles Island Arch (Appendix Figure B-14). This pattern takes into account the distribution of sighting records, as well as the known habitat preferences of *Tursiops* globally. There is a low or unknown occurrence of this species seaward of the area of expected occurrence to account for the possibility of encountering bottlenose dolphins there (based on *Tursiops* distribution in other locales such as the eastern tropical Pacific and off the southeastern U.S.) and for little dedicated survey effort in the area. There is a concentrated occurrence of bottlenose dolphins from the coast to outside of the continental shelf break over the upper continental slope based on the concentration of reported sightings in the PROA/St. Croix OPAREA and globally. Occurrence patterns are expected to be the same throughout the year.

Behavior and Life History—*Tursiops* are very gregarious; they are typically found in groups of 2 to 15 individuals, although groups of 100 have been reported (Shane et al. 1986). Mignucci-Giannoni (1989, 1998) reported a mean group size of 7.8 individuals in the waters of Puerto Rico and the Virgin Islands. Based on photo-identification techniques using dorsal fin shapes and markings (Würsig and Würsig 1977), it is well known that *Tursiops* has a fluid social organization (Connor et al. 2000). *Tursiops* are often associated with other cetaceans (Baird et al. 1993a). Habitat structure, in terms of complexity and water depth, is generally a major force that shapes *Tursiops* groupings (Shane et al. 1986). Shallow-water areas typically have smaller group sizes than open or oceanic areas. Open coastlines, however, differ in habitat structure and prey distribution from more protected areas. Protected areas have been found to foster relatively small school sizes, some degree of regional site fidelity, and limited movement patterns (Wells et al. 1987). In contrast, semi-open habitats often sustain larger school sizes, diminished levels of site fidelity, and more expansive home ranges (Defran and Weller 1999).

Little is known of the behavior or ranging patterns of offshore bottlenose dolphins. The range of offshore bottlenose dolphins may include waters beyond the continental slope (Wells et al. 1999). Wells et al. (1999) even found that offshore bottlenose dolphins may move between the Atlantic and the Gulf of Mexico. Nearshore dolphins exhibit a full spectrum of movements, including seasonal migrations, year-round home ranges, periodic residency, and a combination of occasional long-range movements and repeated local residency (Wells and Scott 1999).

Along the Atlantic coast of the U.S., male and female bottlenose dolphins reach physical maturity at 13 years, with females reaching sexual maturity as early as 7 years (Mead and Potter 1990). Bottlenose dolphins are flexible in their timing of reproduction. Seasons of birth for bottlenose dolphin populations are likely responses to seasonal patterns of availability of local resources (Urian et al. 1996). For the same central U.S. Atlantic coast areas, Hohn (1980) reported one (spring) and possibly two calving seasons (spring, fall), whereas Mead and Potter (1990) reported a prolonged calving season with a spring peak. Rodríguez Ferrer (2001) reported a calving peak in mid-summer (July through August) in Puerto Rican waters. There is a gestation period of one year (Caldwell and Caldwell 1972). Calves of bottlenose dolphins typically remain with their mothers for 3 to 6 years (Wells et al. 1987).

Tursiops are opportunistic feeders that use a wide variety of feeding strategies, taking a wide variety of fishes, cephalopods, and shrimps (Shane 1990; Wells and Scott 1999). Barros and Myrberg (1987) speculated that bottlenose dolphins might detect and perhaps orient to fish prey by listening for the sounds they produce. Nearshore bottlenose dolphins prey predominately on coastal fish and cephalopods; offshore individuals prey on pelagic squid and fish species, especially myctophids (lanternfishes) (Mead and Potter 1995). Unidentified fish bones and squid (*Loligo* spp.) were found in two animals recovered from Puerto Rico and the Virgin Islands whose stomach contents were documented (Mignucci-Giannoni 1996).

Bottlenose dolphins can reach maximum diving depths of about 390 m, with dive durations of 8 or 9 min; it is very common for them to dive to depths of 200 m, with dive durations of 4 min (Ridgway 1986).

Acoustics and Hearing—Sounds emitted by bottlenose dolphins have been classified into two broad categories: pulsed sounds (including clicks and burst-pulses) and narrow-band continuous bands (whistles), which usually are frequency modulated. Clicks and whistles have a dominant frequency range of 110 to 130 kHz and a source level of 218 to 228 dB re 1 µPa-m (Au 1993) and 3.5 to 14.5 kHz and 125 to 173 dB re 1 µPa-m, respectively (Ketten 1998). Generally, whistles range in frequency from 4 to 20 kHz, though Schultz et al. (1995) described whistles with fundamental frequencies entirely below 2 kHz.

The bottlenose dolphin has a functional high-frequency hearing limit of 160 kHz (Au 1993) and can hear sounds at frequencies as low as 40 to 125 Hz (Turl 1993). Inner ear anatomy of this species has been described (Ketten 1992). Electrophysiological experiments suggest that the bottlenose dolphin brain has a dual analysis system: one specialized for ultrasonic clicks and the other for lower-frequency sounds, such as whistles (Ridgway 2000). The audiogram of the bottlenose dolphin shows that the lowest thresholds occurred near 50 kHz at a level around 45 dB re 1 µPa-m, with 10 dB-down bandwidth extending from 15 to 110 kHz (Nachtigall et al. 2000). Below the frequency region of maximum sensitivity, thresholds increased continuously up to a level of 137 dB at 75 Hz. Above 50 kHz, thresholds increased slowly up to a level of 55 dB at 100 kHz, then increased rapidly above this to about 135 dB at 150 kHz. Scientists have reported a range of best sensitivity between 25 and 70 kHz, with peaks in sensitivity occurring at 25 and 50 kHz at levels of 47 and 46 dB re 1 µPa-m (Nachtigall et al. 2000). Richardson (1995) noted that the differences between the reported audiograms for these two studies might be attributable in part to tank problems. A neurophysiological method was used to determine the high-frequency audiograms (5 to 200 kHz) of five bottlenose dolphins (Richardson 1995). Temporary threshold shifts (TTS) in hearing have been experimentally induced in captive bottlenose dolphins (Ridgway et al. 1997). Changes in behavior were observed at the following minimum levels for 1 sec tones: 186 dB at 3 kHz, 181 dB at 20 kHz, and 178 dB at 75 kHz. TTS levels were 194 to 201 dB at 3 kHz, 193 to 196 dB at 20 kHz, and 192 to 194 dB at 75 kHz.

- Pantropical Spotted Dolphin (*Stenella attenuata*)

Description—The pantropical spotted dolphin is a generally slender dolphin. This species has a dark dorsal cape, while the lower sides and belly are gray in adults (Perrin and Hohn 1994). The beak is long and thin; the lips and beak tip tend to be bright white (Jefferson et al. 1993). A dark gray band encircles each eye and continues forward to the apex of the melon; there also is a dark gape-to-flipper stripe (Jefferson et al. 1993). Adults are up to 2.6 m in length (Jefferson et al. 1993). Spotted dolphins are born spotless and develop spots as they age (Perrin and Hohn 1994).

Status—There are no abundance estimates for this species in the Caribbean.

Habitat Preferences—In the eastern Pacific, the pantropical spotted dolphin is found most often in waters underlain by a sharp thermocline at depths of less than 50 m and with water temperatures over 25ºC and salinities less than 34 practical salinity units (psu) (Au and Perryman 1985). Pantropical spotted dolphins in the Gulf of Mexico do not appear to have a preference for any one habitat (within the Loop Current, inside a cold-core eddy, or along the continental slope) (Baumgartner et al. 2001).

Distribution—The pantropical spotted dolphin is distributed in tropical and subtropical waters worldwide (Perrin and Hohn 1994). Most sightings of this species in the Gulf of Mexico occur over the lower continental slope (Davis et al. 1998).

Caldwell et al. (1971) reported on catches of spotted dolphin at the Lesser Antillean island of St. Vincent. From photographs in Caldwell et al. (1971), these animals have since been re-identified as pantropical spotted dolphins (Jefferson personal communication).

- Information Specific to PROA/St. Croix OPAREA—The pantropical spotted dolphin is an oceanic species (Jefferson et al. 1993). Based on the known habitat preferences of the pantropical spotted dolphin, this species is expected to occur from the shelf break to the 3,000 m isobath

both north and south of Puerto Rico and the Virgin Islands, following the outline of the Antilles Island Arch (Appendix Figure B-15). There is a low or unknown occurrence of the pantropical spotted dolphin in waters seaward of the area of expected occurrence, based on the low dedicated survey effort in this OPAREA. Pantropical spotted dolphin occurrence in the PROA/St. Croix OPAREA is assumed to be the same throughout the year.

Behavior and Life History—Group size for the pantropical spotted dolphin may range from just a few dolphins to several thousand (Jefferson et al. 1993). Observations of dolphin groups caught in tuna purse seines in the eastern tropical Pacific show that there are subgroups containing mother/calf pairs, adult males, or juveniles (Pryor and Shallenberger 1991). In the eastern tropical Pacific, where this species has been best studied, there are two calving peaks–one in spring and one in fall (Perrin and Hohn 1994). Pantropical spotted dolphins prey on epipelagic fish, squid, and crustaceans, with some take of mesopelagic animals (Perrin and Hohn 1994). Results from various tracking and food habit studies suggest that pantropical spotted dolphins in the eastern tropical Pacific and off Hawaii feed primarily at night on epipelagic species and on mesopelagic species which rise towards the water's surface after dark (Robertson and Chivers 1997; Scott and Cattanach 1998; Baird et al. 2001). Dives during the day generally are shorter and shallower than dives at night; rates of descent and ascent are higher at night than during the day (Baird et al. 2001). Similar mean dive durations and depths have been obtained for tagged pantropical spotted dolphins in the eastern tropical Pacific and off Hawaii (Baird et al. 2001).

Acoustics and Hearing—Pantropical spotted dolphin whistles have a dominant frequency range of 6.7 to 17.8 kHz (Ketten 1998). No information is available on the hearing capability of this species. Anatomy of the ear of this species has been studied (Ketten 1992, 1997).

- Atlantic Spotted Dolphin (*Stenella frontalis*)

Description—The Atlantic spotted dolphin tends to resemble the bottlenose dolphin more than it does the pantropical spotted dolphin (Jefferson et al. 1993). In body shape, it is somewhat intermediate between the two, with a moderately long but rather thick beak. Adults are up to 2.3 m long and 143 kilograms (kg) in weight (Jefferson et al. 1993). There is marked regional variation in adult body size and spotting of the Atlantic spotted dolphin (Perrin et al. 1987; Perrin 2002). There are two forms: a robust, heavily spotted form that inhabits the continental shelf, usually found within 250 to 350 km of the coast, and a smaller, less-spotted form that inhabits offshore waters (Perrin et al. 1994a). The largest body size is exhibited by Atlantic spotted dolphins occurring in waters over the continental shelf of North America (U.S. east coast, Gulf of Mexico, and Central America) (Perrin 2002). The smallest Atlantic spotted dolphins are those around oceanic islands such as the Azores and on the high seas in the western North Atlantic. Animals from the offshore Caribbean are intermediate in size and degree of spotting between continental and oceanic forms.

Spotted dolphins are born spotless and develop spots as they age (Perrin et al. 1994a). Some Atlantic spotted dolphin individuals become so heavily spotted that the dark cape and spinal blaze are difficult to see.

Status—There are no abundance estimates for this species for the Caribbean.

Habitat Preferences—The large, heavily spotted coastal form of the Atlantic spotted dolphin typically occurs over the continental shelf inside or near the 185 m isobath, usually at least 8 to 20 km offshore (Perrin 2002). In the Gulf of Mexico, this species appears to prefer shallow water with a gently sloping bottom typical of the Gulf of Mexico continental shelf, although it may also occur along the shelf break and upper continental slope (Davis et al. 1998).

Distribution—The Atlantic spotted dolphin, as its name suggests, is endemic to the tropical and warm-temperate Atlantic, from approximately 45ºN to approximately 35ºS in the west, and to the coast of Africa from Mauritania south to at least Gabon in the east (Perrin 2002). This species is typically seen on the continental shelf throughout its distribution (Perrin et al. 1994a; Davis et al.

1998; Mignucci-Giannoni 1998); however, there are often sightings beyond the shelf break in the Caribbean, Gulf of Mexico, and off the Atlantic U.S. coast (Mills and Rademacher 1996; Roden and Mullin 2000). As noted by Perrin et al. (1987), the distribution of the Atlantic spotted dolphin in the Caribbean is poorly known. Mass strandings of Atlantic spotted dolphins occurred on St. John in September 1970 and October 1994 (Rodríguez-López et al. 1995).

- Information Specific to PROA/St. Croix OPAREA—The Atlantic spotted dolphin may occur in both shelf and offshore waters (Perrin et al. 1994a). The Atlantic spotted dolphin is expected to occur from the coastline to the 3,000 m isobath to the north and south of Puerto Rico, following the outline of the Antilles Island Arch (Figure B-16). The Atlantic spotted dolphin typically occurs on the continental shelf, which is supported by the sightings on the shelf. There are also sightings seaward of the continental shelf break, which may be a reflection of the "oceanic island" form. There is a low or unknown occurrence of the Atlantic spotted dolphin in waters seaward of the area of expected occurrence. This takes into account the reported sightings of spotted dolphins identified to be Atlantic spotted dolphins, but which could be misidentified pantropical spotted dolphins. The latter is an oceanic species, sighted more often in waters seaward of the shelf break than the former species. Atlantic spotted dolphin occurrence in the PROA/St. Croix OPAREA is assumed to be the same throughout the year.

Behavior and Life History—Atlantic spotted dolphins are found in small to moderate groups of generally less than 50 individuals (Jefferson et al. 1993). Very little is known about the life history of this species (Perrin et al. 1994a). A satellite-tagged Atlantic spotted dolphin was found to prefer shallow-water habitat and make short, shallow dives on the continental shelf of the Gulf of Mexico (Davis et al. 1996). This species feeds on small cephalopods, fish, and benthic invertebrates (Perrin et al. 1994a). Stomach contents of three Atlantic spotted dolphins that stranded in Puerto Rico consisted of squid beaks from *Illex* sp. (Mignucci-Giannoni 1996).

Acoustics and Hearing—Whistles, clicks, squawks, barks, growls, and chirps have been recorded for the Atlantic spotted dolphin (Thomson and Richardson 1995). Whistles have dominant frequencies ranging from 6.7 to 17.8 kHz. Clicks have a frequency range of 1 to 8 kHz, squawks have a range of 0.1 to 3 kHz, and chirps have a range of 4 to 8 kHz. There are no hearing data for this species.

- Spinner Dolphin (*Stenella longirostris*)

Description—This is a slender dolphin that has a very long, slender beak (Jefferson et al. 1993). The dorsal fin ranges from slightly falcate to triangular. The spinner dolphin generally has a dark eye-to-flipper stripe and dark lips and beak tip (Jefferson et al. 1993). This species has a three-part color pattern (dark gray cape, light gray sides, and white belly). Adults can reach 2.4 m in length (Jefferson et al. 1993).

Status—There are no abundance estimates for this species in the Caribbean.

Habitat Preferences—Distribution of this species in the Gulf of Mexico and off the northeastern U.S. coast has occurred primarily in deeper waters (bottom depth greater than 2,000 m) (CETAP 1982; Davis et al. 1998). However, in most tropical waters, populations of spinner dolphins are known to occur near many oceanic atolls, reefs, and islands (Perrin and Gilpatrick 1994; Wells and Norris 1994; Poole 1995), where deep waters are close to shore. Mignucci-Giannoni (1998) reported that 73% of spinner dolphin sightings in the northeastern Caribbean were in continental shelf waters. Spinner dolphins in the Hawaiian Islands, off the island of Moorea, French Polynesia, and at Fernando de Noronha Island off northern Brazil are known to use sheltered shallow bays for resting areas during the day and move offshore into deeper waters to engage in nighttime feeding activities, feeding on the deep-scattering layer (Lodi and Fiori 1987; Perrin and Gilpatrick 1994; Wells and Norris 1994). In the eastern tropical Pacific, spinner dolphins are found in a habitat typified by unusual conditions of shallow mixed layer, shoal and sharp thermocline, and a relatively small annual variation in surface temperature (Au and Perryman 1985).

Distribution—The spinner dolphin is found in tropical and subtropical waters worldwide. Limits are near 40ºN and 40ºS (Jefferson et al. 1993). Spinner dolphins have been reported for various locations in the northeastern Caribbean (Mignucci-Giannoni 1998). Caldwell et al. (1971) reported spinner dolphin catches in the small cetacean fishery at the Lesser Antillean island of St. Vincent.

- Information Specific to PROA/St. Croix OPAREA—Based on the known habitat preferences of the spinner dolphin near oceanic islands, this species is expected to be found from the coast to the 3,000 m isobath to the north and south of Puerto Rico and the Virgin Islands, following the outline of the Antilles Island Arch (Figure B-17). Spinner dolphin sightings are concentrated in shallow waters to the 1,000 m isobath. There is a low or unknown occurrence of this species seaward of the 3,000 m isobath (Figure B-17). This takes into account the possibility of encountering this species in deeper waters, since it is considered to be an oceanic species, as well as the low survey effort in these waters.

Behavior and Life History—Group sizes range from less than 50 up to several thousand individuals (Jefferson et al. 1993). A Hawaiian population of spinner dolphins was studied for more than 20 years (Norris et al. 1994). Social groupings in this species are very fluid. Large groups form, break down, and re-form with different subgroups throughout the day. In the offshore eastern tropical Pacific, there is some segregation by age and sex among dolphin groups (Perrin and Gilpatrick 1994). Calving peaks in different populations range from late spring to fall (Jefferson et al. 1993). Spinner dolphins feed primarily on small mesopelagic fishes, squids, and sergestid shrimps, diving to at least 200 to 300 m (Perrin and Gilpatrick 1994). Many of these organisms become available to spinner dolphins when the deep scattering layer moves toward the surface at night. Feces and vomit of spinner dolphins has been observed to be a food source for some reef fishes (Silva-Jr. et al. 2001).

In the eastern tropical Pacific, spinner dolphins are often seen with pantropical spotted dolphins (Perrin and Gilpatrick 1994). Spinner dolphins in the Atlantic occasionally have been sighted and found stranded in association with Clymene dolphins (Fertl et al. 2001) and pantropical spotted dolphins (Jefferson and Lynn 1994).

Acoustics and Hearing—Pulses, whistles, and clicks have been recorded from this species. Pulses and whistles have dominant frequency ranges of 5 to 60 kHz and 8 to 12 kHz, respectively (Ketten 1998). Clicks have a dominant frequency of 60 kHz (Ketten 1998). There are no hearing data available for this species.

- Striped Dolphin (*Stenella coeruleoalba*)

Description—The striped dolphin is uniquely marked with black lateral stripes from eye to flipper and eye to anus. There is also a white V-shaped “shoulder blaze” originating above and behind the eye and narrowing to a point below and behind the dorsal fin (Leatherwood and Reeves 1983). This is a relatively robust dolphin reaching 2.6 m in length (Jefferson et al. 1993).

Status—There are no abundance estimates for this species in the Caribbean.

Habitat Preferences—Striped dolphins are usually found beyond the continental shelf, typically over the continental slope out to oceanic waters, often associated with convergence zones and waters influenced by upwelling (Au and Perryman 1985). In the eastern Pacific, striped dolphins inhabit areas with large seasonal changes in surface temperature and thermocline depth (Au and Perryman 1985).

Distribution—The striped dolphin has a worldwide distribution in cool-temperate to tropical waters. Striped dolphins in the western North Atlantic range from Nova Scotia to at least Jamaica and the Gulf of Mexico. For the Caribbean, there are a few sighting and stranding records (van Bree 1975; Jefferson and Lynn 1994; Debrot et al. 1998; Mignucci-Giannoni 1996; Roden and Mullin 2000).

- Information Specific to PROA/St. Croix OPAREA—There is a low or unknown occurrence of the striped dolphin in the PROA/St. Croix OPAREA throughout the year outside of the continental shelf break (Figure B-18). There is little empirical data on the occurrence of striped dolphins in this area. In tropical areas, this species is usually found in waters influenced by upwelling (Au and Perryman 1985; Jefferson personal communication). While striped dolphins are generally more abundant in upwelled areas, the regions of their high-density occurrence tend to be sporadic in distribution (Jefferson personal communication). Without more sighting data obtained from this OPAREA, it is unknown if this species would occur in high densities anywhere in the region.

Behavior and Life History—Striped dolphins are found in groups numbering between 100 and 500 individuals, though sometimes in the thousands. Striped dolphins have been found in association with seabirds and other species of marine mammals (Baird et al. 1993b).

Life history information is based mostly on western North Pacific specimens (Archer and Perrin 1999). Males enter sexual maturity between 7 and 15 years of age, at an average body length of 2.2 m. Females become sexually mature between 5 and 13 years of age. Off Japan, where the biology has been best studied, there are two calving peaks: one in summer, another in winter (Perrin et al. 1994b).

Striped dolphins often feed in pelagic or benthopelagic zones along or seaward of the continental slope. The majority of the prey has luminescent organs, suggesting that striped dolphins may be feeding at great depths, possibly diving to 200 to 700 m to reach potential prey (Archer and Perrin 1999). Striped dolphins may feed at night in order to take advantage of the deep scattering layer's diurnal vertical movements. Small, mid-water fishes (in particular, myctophids or lanternfish) and squids are the dominant prey (Perrin et al. 1994b).

Acoustics and Hearing—Striped dolphin whistles range from 6 to 24+ kHz, with dominant frequencies ranging from 8 to 12.5 kHz (Thomson and Richardson 1995). The range of best hearing for the striped dolphin was determined to be 32 to 120 kHz (Kastelein et al. 2001).

- Clymene Dolphin (*Stenella clymene*)

Description—The Clymene dolphin is easily confused with the spinner dolphin, due to its similar appearance. The Clymene dolphin, however, is smaller and more robust, with a much shorter and stockier beak. A three-part color pattern, a dark gray cape, light gray sides, and white belly, is characteristic of this species (Jefferson et al. 1993). The cape dips in two places, above the eye and below the dorsal fin. The lips and beak tip are black. There is also a dark stripe on the top of the beak, as well as a dark “moustache” on the middle of the top of the beak (Jefferson et al. 1993). Clymene dolphins reach at least 2.0 m in length, with weights of at least 85 kg (Jefferson et al. 1993).

Observations and descriptions of oceanic tropical dolphins of the genera *Stenella* and *Delphinus* in this region prior to 1981 may be unreliable due to the lack of recognized species status for the Clymene dolphin until that time, which may have led to misidentifications (Perrin et al. 1981; Mullin et al. 1994a).

Status—There are no abundance estimates for this species in the Caribbean.

Habitat Preferences—Clymene dolphins have been primarily sighted in deep water. In the Gulf of Mexico, where the most information for this species is available, Clymene dolphins are typically found in deep waters with a mean bottom depth of over 2,000 m (Mullin et al. 1994a; Fertl et al. 2001). In a study of habitat preferences in the Gulf of Mexico, Clymene dolphins were found more often on the lower slope and deepwater regions in areas of cyclonic or confluence circulation (Davis et al. 2002).

Distribution—The Clymene dolphin is known only from the tropical and subtropical Atlantic. There have been many reported sightings of this species in the Gulf of Mexico. Groups of Clymene dolphins have been observed around the Lesser Antillean island of St. Vincent (Watkins and Moore 1982), and

catches in that island's small cetacean fishery have been recorded (Perrin and Mead 1994). As noted by Perrin and Mead (1994), the Clymene dolphin can be expected throughout the Caribbean. However, this species has not yet been reported off Puerto Rico.

- Information Specific to PROA/St. Croix OPAREA—While this species is known to occur in the Caribbean, there are currently no records of this species for the PROA/St. Croix OPAREA. As a tropical species, this species might be found in this area throughout the year. The Clymene dolphin is most often sighted in deep waters. Therefore, there is a low or unknown occurrence of the Clymene dolphin seaward of the continental shelf break throughout the year (Figure B-19).

Behavior and Life History—Very little is known about the Clymene dolphin (Jefferson 2002b); much of the information comes from the northern Gulf of Mexico (Jefferson et al. 1995). Sexual maturity appears to be reached by the length of 1.8 m (Jefferson 1996). Mean reported group size is 131 individuals (range is from several to 1,000 individuals) (Fertl et al. 2001). Clymene dolphins are known to associate with other dolphin species, such as spinner dolphins. Available information on feeding habits is limited to the stomach contents of two individuals and one observation of free-ranging dolphins; Clymene dolphins feed on small fish and squid (Perrin et al. 1981; Fertl et al. 1997).

Acoustics and Hearing—The only available information on Clymene dolphin acoustics is regarding their whistles (Mullin et al. 1994a). The structure of Clymene whistles is similar to that of other species of the genus *Stenella* but generally with higher frequencies (6.3 to 19.2 kHz). There are no data on the hearing capability of this species.

- Common Dolphins (*Delphinus* spp.)

Description—There are two species in the genus *Delphinus*: the long-beaked common dolphin (*Delphinus capensis*) and the short-beaked common dolphin (*Delphinus delphis*) (Heyning and Perrin 1994; Rosel et al. 1994). Common dolphins are moderately slender animals with a medium to long beak and a tall, slightly falcate dorsal fin. Common dolphins are distinctively marked, having a V-shaped dark saddle that produces an hourglass pattern on the side of the body (Jefferson et al. 1993). The back is a dark, brownish gray; the belly is white; and the anterior flank patch is tan to cream in color. The lips are dark and there is a stripe running from the apex of the melon to encircle the eye. There is also a black to dark gray chin-to-flipper stripe, which may encompass the gape in long-beaked animals. Adults can reach lengths of up to 2.6 m (Jefferson et al. 1993).

Status—There are no abundance estimates for common dolphins in the Caribbean.

Habitat Preferences—Common dolphins occupy a wide range of habitats including waters over the continental shelf, along the continental shelf break, and over prominent underwater topography (e.g., mid-Atlantic Ridge and seamounts) (Hui 1979; Evans 1994). Common dolphins in some populations appear to preferentially travel along bottom topographic features such as escarpments and seamounts (Evans 1994). In tropical regions, where common dolphins are routinely sighted, they are found in upwelling-modified waters (Au and Perryman 1985; Ballance and Pitman 1998).

Distribution—*Delphinus* is a widely distributed genus of cetacean. It is found worldwide in temperate, tropical, and subtropical seas. Records of the short-beaked common dolphin from the western North Atlantic range from at least Florida to Newfoundland (Heyning and Perrin 1994). The long-beaked common dolphin is known from the coast of eastern South America, from Venezuela to northern Argentina (Heyning and Perrin 1994).

There are only sighting records (no strandings) for *Delphinus* off Puerto Rico and the Virgin Islands (Mignucci-Giannoni 1989). Caribbean Sea *Delphinus* sightings without photographic records should be viewed with caution (Roden and Mullin 2000; Jefferson personal communication). For example, all reports of *Delphinus* spp. from the Gulf of Mexico were actually misidentified Clymene and spinner dolphins (Jefferson and Schiro 1997). Evans (1994) additionally noted that pantropical spotted dolphins could be misidentified as common dolphins.

- Information Specific to PROA/St. Croix OPAREA—There is a low or unknown occurrence of common dolphins throughout the year from the coast to the 3,000 m isobath north and south of Puerto Rico and the Virgin Islands, following the outline of the Antilles Island Arch (Figure B-20). Globally, the common dolphin occurs over the continental shelf and into deeper waters.

  None of the records for the PROA/St. Croix OPAREA are verifiable, since no photographs or detailed descriptions are available. These records should be considered suspect (Jefferson personal communication; Roden and Mullin 2000). It would not be unreasonable to consider the possibility that these reported sightings of common dolphins might actually be misidentified Clymene dolphins. The common dolphin sightings were made prior to 1981, before the Clymene dolphin was verified as its own species. In tropical regions, common dolphins are found routinely in upwelling-modified waters (Au and Perryman 1985; Ballance and Pitman 1998). Additionally, in the three NMFS surveys that have taken place since 1995, there have been no sightings of the common dolphin. Another possibility for the sightings is some anomaly in oceanographic conditions. There is sparse survey effort in this area, so it is difficult to determine the cause for this distributional variability or anomaly. If these are indeed common dolphins, perhaps there was some concentrated prey occurrence in the area at the time of the sightings.

Behavior and Life History—Group size ranges from several dozen to over 10,000 (Jefferson et al. 1993). Common dolphins are fast-moving swimmers, active bowriders, and often jump in the air. Calving peaks differ from stock to stock. Calving peaks in spring and autumn, or spring and summer, have been reported (Jefferson et al. 1993). *Delphinus* feed on a wide variety of epipelagic and mesopelagic schooling fishes and squids in the deep scattering layer. Common dolphins feed opportunistically on those species most abundant locally and change their diet according to fluctuations in the abundance and availability of prey (Young and Cockcroft 1994). Based on a small sample size from the eastern North Pacific, the short-beaked common dolphin may feed more extensively on squid than the long-beaked form (Heyning and Perrin 1994). Diel fluctuations in vocal activity of this species (more vocal activity during late evening and early morning) appear to be linked to feeding on the deep scattering layer as it rises during the same time (Goold 2000).

Acoustics and Hearing—Recorded *Delphinus* vocalizations include whistles, chirps, barks, and clicks (Ketten 1998). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998). Popov and Klishin (1998) recorded auditory brainstem responses from a common dolphin. The audiogram was U-shaped with a steeper high-frequency branch. The audiogram bandwidth was up to 128 kHz at a level of 100 dB above the minimum threshold. The minimum thresholds were observed at frequencies of 60 to 70 kHz.

- Fraser's Dolphin (*Lagenodelphis hosei*)

Description—Fraser's dolphin reaches a maximum length of 2.7 m and is generally more robust than other small delphinids (Jefferson et al. 1993). This species has a short beak, small flippers, and a subtriangular dorsal fin. The most conspicuous feature of the Fraser's dolphin coloration is the dark band running from the face to the anus in some individuals (Jefferson et al. 1993), although it is not present in younger animals (Jefferson personal communication). The stripe is set off from the surrounding areas by thin, pale, cream-colored borders. There is also a dark chin-to-flipper stripe.

Status—There are no abundance estimates for this species in the Caribbean.

Habitat Preferences—This is an oceanic species. In the Gulf of Mexico, this species has been seen in waters out over the abyssal plain (Jefferson personal communication). In the offshore eastern tropical Pacific, this species is distributed mainly in upwelling-modified waters (Au and Perryman 1985).

Distribution—Fraser's dolphin is found in tropical waters around the world, typically between 30ºN and 30ºS (Jefferson et al. 1993). Strandings in temperate areas are considered extralimital and usually are associated with anomalously warm-water temperatures (Perrin et al. 1994c). There are

few records from the Atlantic Ocean, in particular, the Caribbean (Leatherwood et al. 1993). There are seven records of Fraser's dolphin for the Caribbean Sea including three individuals taken by the small cetacean fishery off the Lesser Antillean island of St. Vincent in 1972 and 1976 and two strandings on Puerto Rico (Caldwell et al. 1976; Watkins et al. 1994; Mignucci-Giannoni et al. 1999c).

- Information Specific to PROA/St. Croix OPAREA—The Fraser's dolphin is an oceanic species. As noted earlier, there are few records from the Caribbean for the Fraser's dolphin. In the Gulf of Mexico, this species has been seen in waters over the abyssal plain (Leatherwood et al. 1993). There is, therefore, a low or unknown occurrence of the Fraser's dolphins from the vicinity of the continental shelf break to past the boundaries of the OPAREA (Figure B-21). The occurrence is assumed to be the same for all seasons.

Behavior and Life History—Fraser's dolphins are usually seen in large, fast-moving groups. Most sightings have been of groups ranging between 100 and 1,000 individuals. This species has been seen in mixed-species aggregations with melon-headed whales in the eastern tropical Pacific and Gulf of Mexico. Very little is known of the natural history of the Fraser's dolphin, including reproduction. Available data do not show strong evidence of calving seasonality. Sexual maturity for both sexes occurs at about 7 years of age in the eastern North Atlantic Ocean (Jefferson and Leatherwood 1994). Fraser's dolphins feed on mid-water fishes, squids, and shrimps (Caldwell et al. 1976; Jefferson and Leatherwood 1994; Perrin et al. 1994c; Mignucci-Giannoni et al. 1999c). Fraser's dolphins have been observed feeding on rainbow runner (*Elagatis bipinnulatus*) off Dominica in the southeastern Caribbean (Watkins et al. 1994). There is no information available on depths to which Fraser's dolphins may dive, but they are thought to be capable of deep dives.

Acoustics and Hearing—Fraser's dolphin whistles have a frequency range of 7.6 to 13.4 kHz (Leatherwood et al. 1993). There are no hearing data for this species.

- Risso's Dolphin (*Grampus griseus*)

Description—Risso's dolphins are moderately large, robust animals reaching at least 3.8 m in length (Jefferson et al. 1993). The head is blunt, without a distinct beak, and there is a vertical crease on the front of the melon. The dorsal fin is tall and falcate. Young Risso's dolphins range from light gray to dark brownish gray and are relatively unmarked (Jefferson et al. 1993). Adults range from dark gray to nearly white and are covered with white scratches and splotches.

Status—There are no abundance estimates for this species for the Caribbean.

Habitat Preferences—A number of studies have noted that Risso's dolphins are found along the continental slope (CETAP 1982; Baumgartner 1997; Davis et al. 1998; Kruse et al. 1999). Similarily in the area of Puerto Rico and the Virgin Islands, Risso's dolphins are distributed in areas of steep bathymetric slope (Mignucci-Giannoni 1998). Baumgartner (1997) hypothesized that the strong correlation between Risso's dolphin distribution and the steeper portions of the upper continental slope in the Gulf of Mexico is most likely the result of cephalopod distribution in the same area.

Distribution—The Risso's dolphin is distributed worldwide in tropical and warm-temperate waters, roughly between 60ºN and 60ºS latitude, where surface water temperature is usually greater than 10ºC (Kruse et al. 1999). Catches in the St. Vincent pilot whale fishery in the Lesser Antilles are the most southern records for this species in the western North Atlantic (Caldwell et al. 1971).

- Information Specific to PROA/St. Croix OPAREA—Risso's dolphins are expected to occur in the PROA/St. Croix OPAREA from the shelf break to the 3,000 m isobath north and south of Puerto Rico and the Virgin Islands, following the outline of the Antilles Island Arch (Figure B-22). While there is a predominance of Risso's dolphin sightings worldwide in areas with steep bottom topography, this species is also found in deep oceanic waters, as observed in the Gulf of Mexico and Charleston-Jacksonville OPAREAs. There is an area of low or unknown occurrence seaward of the area of expected occurrence, which extends past the boundaries of the PROA/St. Croix

OPAREA throughout the year. This is based on the low survey effort in those waters and the possibility of encountering the Risso's dolphin in those waters. The occurrence of Risso's dolphins is assumed to be the same for all four seasons.

There is also a low or unknown occurrence of the Risso's dolphin from the 30 m isobath to the shelf break. This takes into account the sporadic sightings in more shallow waters in other areas, such as the Gulf of Mexico and along the Atlantic U.S. It also considers the possibility that this species, with a preference for waters with steep bottom topography, might swim into areas where deep water is close to shore. Leatherwood et al. (1979) and Shane (1994) reported on sightings of Risso's dolphins in shallow waters in the northeastern Pacific, including near oceanic islands. These sites are in areas where the continental shelf is narrow and deep water is closer to the shore (Leatherwood et al. 1979).

Behavior and Life History—Little is known about the life history of this species. In the North Atlantic, there appears to be a summer calving peak (Jefferson et al. 1993). Risso's dolphins are quite social–groups usually average about 30 individuals, but can range up to over several hundred (Kruse et al. 1999). Risso's dolphins occur in stable, age- and sex-segregated groups, which interact fluidly with a larger population. Risso's dolphins also commonly associate with other cetacean species (CETAP 1982). Risso's dolphins may remain submerged on dives for 30 min; typical swimming speed is 1.67 to 1.94 m/sec (Kruse et al. 1999). Cephalopods are the primary prey (Clarke 1996).

Acoustics and Hearing—Risso's dolphin vocalizations include broadband clicks, barks, buzzes, grunts, chirps, whistles, and simultaneous whistle and burst-pulse sounds (Corkeron and van Parijs 2001). The combined whistle and burst pulse sound appears to be unique to Risso's dolphin (Corkeron and van Parijs 2001). Corkeron and van Parijs (2001) recorded five different whistle types, ranging in frequency from 4 to 22 kHz. Broadband clicks had a frequency range of 6 to greater than 22 kHz. Low-frequency narrowband grunt vocalizations had a frequency range of 0.4 to 0.8 kHz. Nachtigall et al. (1995) conducted baseline audiometric work. Because of the natural background noise (the study was conducted in a natural setting), it was not possible to determine peak (or best) sensitivity in the species. Maximum sensitivity occurred between 8 and 64 kHz. Reported thresholds were 124 dB at 1.6 kHz, 71.7 dB at 4 kHz, 63.7 dB at 8 kHz, 63.3 dB at 16 kHz, 66.5 dB at 32 kHz, 67.3 dB at 64 kHz, 74.3 dB at 80 kHz, 124.2 dB at 100 kHz, and 122.9 dB at 110 kHz.

- Melon-headed Whale (*Peponocephala electra*)

Description—Melon-headed whales at sea closely resemble pygmy killer whales. Melon-headed whales have pointed flippers and a more triangular head shape than pygmy killer whales (Jefferson et al. 1993). The body is charcoal gray to black, with unpigmented lips (which often appear light gray, pink, or white) and a white urogenital patch (Perryman et al. 1994). This species also has a triangular face "mask" and indistinct cape (which dips much lower below the dorsal fin than that of pygmy killer whales) (Perryman et al. 1994). Melon-headed whales reach a maximum length of 2.75 m (Jefferson et al. 1993).

Status—There are no abundance estimates for this species for the Caribbean.

Habitat Preferences—Little information is available on habitat preferences. Most melon-headed whale sightings in the Gulf of Mexico have been in deep waters, well beyond the edge of the continental shelf (Mullin et al. 1994b; Davis and Fargion 1996) and waters out over the abyssal plain (Jefferson personal communication).

Distribution—Melon-headed whales are found worldwide in deep tropical and subtropical waters. There are very few records for melon-headed whales in the North Atlantic. There are nine records for melon-headed whales in the Caribbean, including four captures during the small cetacean fishery off St. Vincent in the Lesser Antilles in 1976 and a stranding in Puerto Rico (Mignucci-Giannoni et al. 1998).

- Information Specific to PROA/St. Croix OPAREA—Melon-headed whales and pygmy killer whales can be difficult to distinguish from one another, and on many occasions, only a determination of "pygmy killer whale/melon-headed whale" can be made. The predicted occurrence of both species is considered similar and was therefore combined (Figure B-23).

  The pygmy killer whale is an oceanic species and there are few records of this species in the OPAREA. In the Gulf of Mexico, this species has been seen in waters out over the abyssal plain (Jefferson personal communication). There is, therefore, a low or unknown occurrence of the pygmy killer whale from the vicinity of the continental shelf break to past the boundaries of the OPAREA (Figure B-23). The occurrence is assumed to be the same for all seasons.

Behavior and Life History—Melon-headed whales are typically found in large groups, ranging between 150 and 1,500 individuals (Perryman et al. 1994), though Watkins et al. (1997) described smaller groupings of 10 to 14 individuals. Melon-headed whales are often found in mixed-species aggregations, commonly with Fraser's dolphins (Jefferson and Barros 1997). Very few data are available on life history. It is unclear whether there is significant seasonality in calving (Jefferson and Barros 1997). Females reach sexual maturity at about 11.5 years and males at 16.5 years (Jefferson and Barros 1997). Melon-headed whales prey on squid, pelagic fishes, and occasionally crustaceans. Most of the fish and squid families eaten by this species consist of mesopelagic species found in waters up to 1,500 m deep, suggesting that feeding takes place deep in the water column (Jefferson and Barros 1997). A melon-headed whale found stranded in Puerto Rico had a few squid beaks and fish scales in its stomach (Mignucci-Giannoni et al. 1998). An individual stranded on the Lesser Antillean island of St. Vincent was found to have partially digested fish and squid, cephalopod beaks, and fish otoliths and bones (Caldwell et al. 1976). There is no information on diving behavior for melon-headed whales.

Acoustics and Hearing—The only published acoustic information for melon-headed whales is from the southeastern Caribbean (Watkins et al. 1997). Sounds recorded included whistles and click sequences. Whistles had dominant frequencies around 8 to 12 kHz; higher-level whistles were estimated at no more than 155 dB re 1 µPa-m. Clicks had dominant frequencies of 20 to 40 kHz; higher-level click bursts were judged to be about 165 dB re 1 µPa-m. No data on hearing ability for this species are available.

- Pygmy Killer Whale (*Feresa attenuata*)

Description—The pygmy killer whale is often confused with the melon-headed whale and the false killer whale. Flipper shape is the best distinguishing characteristic—pygmy killer whales have rounded tips (Jefferson et al. 1993). The body of the pygmy killer whale is somewhat slender, with a rounded head that has no beak (Jefferson et al. 1993). The color of this species is dark gray to black, with a prominent narrow cape that dips only slightly below the dorsal fin and a white to light gray ventral band that widens around the genitals. The lips and snout tip are sometimes white. Pygmy killer whales reach lengths of up to 2.6 m (Jefferson et al. 1993).

Status—There are no abundance estimates for this species for the Caribbean.

Habitat Preferences—In the northern Gulf of Mexico, this species is found primarily in deeper waters off the continental shelf (Davis and Fargion 1996) and waters out over the abyssal plain (Jefferson personal communication).

Distribution—This species has a worldwide distribution in tropical and subtropical waters, generally not ranging north of 40ºN or south of 35ºS (Jefferson et al. 1993). There are few records of this species in the western North Atlantic. There are only three confirmed records of this species in the Caribbean: a capture of a pygmy killer whale in St. Vincent in the Lesser Antilles in 1969 as part of the pilot whale fishery which took place there (Caldwell et al. 1971), a mass stranding of five individuals on Tortola, BVI in September 1995 (Mignucci-Giannoni et al. 1999d), and a stranding on Puerto Rico (Rodriguez-Lopez and Mignucci-Giannoni 1999).

- Information Specific to PROA/St. Croix OPAREA—Pygmy killer whales and melon-headed whales can be difficult to distinguish from one another, and on many occasions, only a determination of "pygmy killer whale/melon-headed whale" can be made. The occurrence of both species is considered similar and therefore appears combined in Appendix Figure B-23.

  The pygmy killer whale is an oceanic species, and there are few records for this OPAREA. In the Gulf of Mexico, this species has been seen in waters out over the abyssal plain (Jefferson personal communication). There is, therefore, a low or unknown occurrence of the pygmy killer whale from the vicinity of the continental shelf break to past the boundaries of the OPAREA (Figure B-23). The occurrence is assumed to be the same for all seasons.

Behavior and Life History—Little is known about the reproductive biology of this species. This species usually forms relatively small herds (Ross and Leatherwood 1994). Pygmy killer whales eat mostly fish and squid, and sometimes attack other dolphins (Ross and Leatherwood 1994). Unidentified squid beaks and fish otoliths were found in the stomachs of the pygmy killer whales that had mass stranded on Tortola, BVI (Mignucci-Giannoni et al. 1999d).

Acoustics and Hearing—The only information available on pygmy killer whale vocalizations is that they "growl and blat" (Thomson and Richardson 1995). There are no hearing data available for this species.

- False Killer Whale (*Pseudorca crassidens*)

Description—The false killer whale is a large, dark gray to black dolphin with a faint gray patch on the chest, and sometimes light gray areas on the head (Jefferson et al. 1993). The false killer whale has a long slender body, a rounded overhanging forehead, and no beak (Jefferson et al. 1993). The dorsal fin is falcate and slender. The flippers have a characteristic hump on the leading edge—this is perhaps the best characteristic in distinguishing this species from the other "blackfish" (pygmy killer, melon-headed, and pilot whales) (Jefferson et al. 1993). Individuals can attain maximum lengths of 6.1 m (Jefferson et al. 1993).

Status—There are no abundance estimates for this species for the Caribbean.

Habitat Preferences—This species is found primarily in oceanic and offshore areas, though they do approach close to shore at oceanic islands (Baird 2002). Most sightings in the Gulf of Mexico have been made in oceanic waters greater than 200 m deep, although there have been sightings in waters over the continental shelf (Davis and Fargion 1996). Seasonal movements in the western North Pacific may be related to prey distribution (Odell and McClune 1999). Inshore movements are occasionally associated with shoreward flooding of warm ocean currents (Stacey et al. 1994).

Distribution—False killer whales are found in tropical and temperate waters, generally between 50ºS and 50ºN latitude with a few records north of 50ºN in the Pacific and the Atlantic (Odell and McClune 1999). False killer whales were included among catches of the St. Vincent pilot whale fishery in the Lesser Antilles (Caldwell et al. 1971).

- Information Specific to PROA/St. Croix OPAREA—There is a low or unknown occurrence of false killer whales throughout the PROA/St. Croix OPAREA during all seasons (Figure B-24). The false killer whale is an oceanic species, occurring in deep waters, and is known to occur close to shore near oceanic islands (Baird 2002). This is likely due to the occurrence of deep water very close to shore near oceanic islands. There are few confirmed sightings of this species in and around the PROA/St. Croix OPAREA (Figure B-24).

Behavior and Life History—This species may occur in large groups (group sizes as large as 300 have been reported) (Brown et al. 1966). Reported traveling speeds are 3 to 6 kn and as high as 10 kn (reviewed in Odell and McClune 1999). There is little information on swimming and diving behavior of this species; they have a maximum known dive depth at about 500 m (Odell and McClune 1999).

No seasonality in breeding is known for the false killer whale (Jefferson et al. 1993). False killer whales primarily eat deep-sea cephalopods and fish (Odell and McClune 1999), but they have been known to attack other toothed whales (Perryman and Foster 1980; Stacey and Baird 1991), including sperm whales (Palacios and Mate 1996) and baleen whales (Jefferson personal communication). False killer whales in many different regions are known to take tuna from longlines (Mitchell 1975).

Acoustics and Hearing—The dominant frequencies of false killer whale whistles are 4 to 9.5 kHz; those of their clicks are 25 to 30 kHz and 95 to 130 kHz (Thomas et al. 1990; Thomson and Richardson 1995). The source level is 220 to 228 dB re 1 μPa-m (Ketten 1998). Best hearing sensitivity measured for a false killer whale was around 16 to 64 kHz (Thomas et al. 1988, 1990).

- Killer Whale (*Orcinus orca*)

Description—The black-and-white color pattern of the killer whale is striking, as is the tall, erect dorsal fin of the adult male (1.0 to 1.8 m in height) (Jefferson et al. 1993). The white oval eye patch and variably shaped saddle patch, in conjunction with the shape and notches in the dorsal fin, help in identifying individuals. The killer whale has a blunt head and large, oval flippers. Females may reach 7.7 m in length and males 9.0 m (Dahlheim and Heyning 1999).

Status—There are no abundance estimates for this species for the Caribbean.

Habitat Preferences—Killer whales can be found in the open sea, as well as in coastal areas (Dahlheim and Heyning 1999). In coastal areas, killer whales often enter shallow bays, estuaries, and river mouths (Leatherwood et al. 1976). Killer whales off Puerto Rico and the Virgin Islands are found in both shelf and offshore waters (Mignucci-Giannoni 1998). Killer whales were observed approximately 54% of the time over the continental shelf, in areas of low sea floor relief (Mignucci-Giannoni 1998). In other regions of the western North Atlantic, the reported concentration of sightings is along the shelf break and farther offshore (Katona et al. 1988; Mitchell and Reeves 1988; Reeves and Mitchell 1988; O'Sullivan and Mullin 1997).

Distribution—This is a cosmopolitan species found throughout all oceans and contiguous seas, from equatorial regions to the polar pack-ice zones. Though found in tropical waters and the open ocean, killer whales as a species are most numerous in coastal waters and higher latitudes (Dahlheim and Heyning 1999). Ford (2002) noted that this species has a sporadic occurrence in most regions. Regular occurrence in the western North Atlantic year-round is in the area south of 35ºN (Katona et al. 1988).

- Information Specific to PROA/St. Croix OPAREA—There is a low or unknown occurrence of killer whales from the coast to the 3,000 m isobath north and south of Puerto Rico and the Virgin Islands, following the outline of the Antilles Island Arch (Figure B-25). There are very few sightings of killer whales in the PROA/St. Croix OPAREA (Figure B-25). Erdman (1970) reported that killer whales were sighted twice off St. Thomas, USVI (no dates were provided to establish seasonal occurrence) and one sighting of an attack of killer whales on a "large whale" southeast of Culebra. Killer whale occurrence in the PROA/St. Croix OPAREA is assumed to be similar year-round.

Behavior and Life History—In all areas where longitudinal studies have been carried out, evidence suggests that there are long-term associations between individuals and limited dispersal from maternal groups (Baird 2000). Killer whales off Puerto Rico and the Virgin Islands have been observed in groups numbering from one to 25 individuals, with the mean group size being 7.7 individuals (Mignucci-Giannoni 1998). There is no published information on killer whale reproductive behavior in the western North Atlantic.

Killer whales feed on bony fishes, elasmobranchs, cephalopods, seabirds, sea turtles, and other marine mammals (Katona et al. 1988; Jefferson et al. 1991; Fertl et al. 1996). Killer whales use passive listening as a primary means of locating prey and use different echolocation patterns for

different hunting strategies (Barrett-Lennard et al. 1996). For example, they mask their clicks and encode their signals in background noise when hunting other cetaceans, prey that can hear their high-frequency clicks. In contrast, killer whales do not mask their high-frequency signals when hunting fish that do not hear in this frequency range. Killer whales in the Caribbean have been observed attacking large and small whales, as well as dolphins, off Culebra and between St. Thomas, USVI and St. Croix, USVI (Erdman 1970; Mignucci-Giannoni 1998). Three killer whales taken off St. Vincent in the Lesser Antilles were found to have leatherback sea turtle remains in their stomachs (Caldwell and Caldwell 1969).

The maximum-recorded depth for a killer whale diving off British Columbia was 173 m; a trained killer whale dove to a maximum of 260 m (Dahlheim and Heyning 1999). The longest recorded dive from a radio-tagged killer whale was 17 min.

Acoustics and Hearing—The killer whale produce a wide variety of clicks and whistles but most of its sounds are pulsed and at 1 to 6 kHz; source levels range up to 160 dB re 1 µPa-m (Thomson and Richardson 1995). Acoustic studies of resident killer whales in British Columbia have found that there are dialects, which are highly stereotyped, repetitive discrete calls that are group-specific and shared by all group members (Ford 2002). These dialects likely are used to maintain group identity and cohesion, and may serve as indicators of relatedness that help in the avoidance of inbreeding between closely related whales (Ford 2002). Dialects have been documented in killer whales occurring in northern Norway, and likely occur in other locales as well (Ford 2002).

The killer whale has the lowest frequency of maximum sensitivity and one of the lowest high-frequency limits among toothed whales (Szymanski et al. 1999). The upper limit of hearing is 100 kHz for this species. The most sensitive frequency, in both behavioral and in auditory brainstem response audiograms, has been determined to be 20 kHz (Szymanski et al. 1999).

- Short-finned Pilot Whales (*Globicephala macrorhynchus*)

Description—There are two species of pilot whales in the western North Atlantic; only the short-finned pilot whale is expected in the Caribbean. Pilot whales are among the largest members of the family Delphinidae (Jefferson et al. 1993). In general, the short-finned pilot whale is smaller than the long-finned pilot whale (Bernard and Reilly 1999). The short-finned pilot whale may reach 5.5 m (females) and 6.1 m (males) in length (Jefferson et al. 1993).

Pilot whales have bulbous heads, with a forehead that sometimes overhangs the rostrum; there is no beak (Jefferson et al. 1993). The dorsal fin is distinctive, being generally broader-based than it is tall. It is falcate and usually rounded at the tip, and is set well forward of the middle of the back. The flippers of the short-finned pilot whale are long and sickle-shaped and range from 16% to 22% of the total body length (Jefferson et al. 1993). Both pilot whale species are black on the back and sides; in some individuals, there is a light gray saddle patch located behind the dorsal fin. Pilot whales have a white to light gray anchor-shaped patch on the chest (Jefferson et al. 1993).

Status—There are no abundance estimates for this species for the Caribbean.

Habitat Preferences—Pilot whales are found in both nearshore and offshore environments (Olson and Reilly 2002). Pilot whales are found over the continental shelf break, in slope waters, and in areas of high topographic relief (Olson and Reilly 2002). Pilot whales are sometimes seen in waters over the continental shelf (Jefferson personal communication). A number of studies have suggested that the distribution and movements of *Globicephala* spp. coincide closely with the abundance of squid (Taruski and Winn 1976; Hui 1985; Payne and Heinemann 1993; Bernard and Reilly 1999). The distribution of *Globicephala* spp. in the Southern California Bight was found to be associated with high relief topography, which Hui (1985) related to the squid-feeding habits of pilot whales. A clear relation of pilot whale distribution to bottom topography off Puerto Rico and the Virgin Islands, however, was not found by Mignucci-Giannoni (1989). Mignucci-Giannoni (1989, 1998) reported that there were

more occurrence records of pilot whales during the winter and spring (January through April) and noted that this seems to coincide with the inshore movement of spawning octopus.

Distribution—The short-finned pilot whale is found worldwide in tropical and warm-temperate seas and usually does not range north of 50ºN or south of 40ºS (Jefferson et al. 1993). The short-finned pilot whale has a wide distribution in the Caribbean (Watkins and Moore 1982; Mattila and Clapham 1989) and is a commonly sighted species. Caldwell et al. (1971) reported on a small fishery for pilot whales on the western side of St. Vincent in the Lesser Antilles, which continues on a lesser scale to this day (Jefferson personal communication).

- Information Specific to PROA/St. Croix OPAREA—All of the OPAREA and vicinity pilot whale records are presumed to be of the short-finned pilot whale, even when identifications past the genus level were not provided (Figure B-26; Jefferson personal communication). The short-finned pilot whale is present year-round in the northeastern Caribbean (Mignucci-Giannoni 1998). Expected occurrence of pilot whales in the PROA/St. Croix OPAREA is from the coast to the 4,000 m isobath north of Puerto Rico and the Virgin Islands and to the 3,000 m isobath to the south (Figure B-26). The distribution of the majority of the sighting records throughout the year was considered, as well as the known preference of this species globally for steep bottom topography, which is most probably related to distribution of squid. The low or unknown occurrence of pilot whales in deeper waters is based on the low survey effort in these waters. There is a concentrated occurrence of this species in waters on the continental shelf and in the deep waters between St. Croix and the rest of the Virgin Islands. This takes into account a large number of sightings on the continental shelf (also noted by Mignucci-Giannoni 1998), as well as the fact that pilot whales likely move between the islands in the PROA/St. Croix OPAREA, which are in close proximity to one another. With a narrow continental shelf and deep waters in close proximity to the shore, it is not surprising that this species is also frequently sighted over the continental shelf. Occurrence patterns are assumed to be the same for all seasons.

Behavior and Life History—Pilot whales are very social and may be seen in groups of several individuals to upwards of several hundreds. Groups in this part of the Caribbean range from one to 100 individuals (Mignucci-Giannoni 1998). Pilot whales appear to live in relatively stable female-based groups (Jefferson et al. 1993). Average age at sexual maturity for short-finned pilot whales is 9 years for females and 17 years for males (Bernard and Reilly 1999). The gestation period for short-finned pilot whales is 15 to 16 months, with a mean calving interval of 4.6 to 5.7 years (Bernard and Reilly 1999). Calving peaks in the northern hemisphere for short-finned pilot whales vary by stock (Jefferson et al. 1993).

Short-finned pilot whales are often sighted in association with other cetaceans (Bernard and Reilly 1999). Roden and Mullin (2000) reported on two interactions between humpback whales and short-finned pilot whales in the northern Caribbean. The short-finned pilot whale is known to mass strand (Caldwell et al. 1970; Toyos-Gonzalez and Mignucci-Giannoni 2001). Pilot whales are deep divers. The pilot whale can stay submerged for over 10 min and the maximum dive depth measured is 610 m (Bernard and Reilly 1999). Mate (1989) described movements of a satellite-tagged, rehabilitated long-finned pilot whale that was released off Cape Cod and ranged from New Jersey to Nova Scotia during the three months of the tag's operation. Daily movements of up to 234 km and swimming speeds averaging 0.92 m/sec were recorded. Deep diving occurred mainly at night, when prey is nearer the water's surface. Tagged long-finned pilot whales in the Ligurian Sea (located between Italy and Corsica) were also found to make their deepest dives (maximum of 648 m) after dark, which is the time that vertically migrating prey become more readily available as they move closer to the surface (Baird et al. 2002).

Short-finned pilot whales feed primarily on squids but also take fish (Bernard and Reilly 1999). Caldwell et al. (1971) reported that both squid and fish were found in pilot whales taken in the pilot whale fishery off the Lesser Antillean island of St. Vincent. Pilot whales have been reported to feed on tuna during the summer off Puerto Rico (Caldwell and Erdman 1963). Stomach content analysis of two animals from Puerto Rico revealed squid beaks (Mignucci-Giannoni 1996). Pilot whales are not

generally known to prey on other marine mammals; however, records from the eastern tropical Pacific suggest that the short-finned pilot whale does chase, attack, and may occasionally eat dolphins during fishery operations (Perryman and Foster 1980), and they have been observed harassing sperm whales (Weller et al. 1996).

Acoustics and Hearing—Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 kHz and a source level of 180 dB re 1 µPa-m (Ketten 1998). There are no hearing data available for this species.

Seals

Although there are many species of seals found in the western North Atlantic, no living seal species normally ranges as far south as the PROA/St. Croix OPAREA. Until the 1950s, the Caribbean monk seal was present in the Caribbean, but is now considered extinct (Le Boeuf et al. 1986). Puerto Rico and the Virgin Islands have never been considered a locality where Caribbean monk seals were usually found (Mignucci-Giannoni 1989). Any sightings of seals represent uncommon extralimital occurrences of animals that strayed from their normal distributional range.

- Hooded Seals (*Cystophora cristata*)

  Hooded seals are found in the Atlantic region of the Arctic Ocean and in high latitudes of the North Atlantic, especially near the outer edge of the pack ice. Hooded seals (particularly young ones) are recognized as great wanderers. They appear in places far from their normal breeding and foraging range and have traveled as far south as Puerto Rico and the Virgin Islands (Mignucci-Giannoni and Odell 2001; Mignucci-Giannoni and Haddow 2002). There are records of dead and live-stranded hooded seals in the PROA/St. Croix OPAREA for May through September (Mignucci-Giannoni and Odell 2001; Mignucci-Giannoni personal communication). These are considered extralimital.

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3.2 SEA TURTLES

3.2.1 Introduction

Sea turtles are long-lived, air-breathing reptiles found throughout the world's tropical, subtropical, and temperate seas (CCC 1996). There are seven living species of sea turtle from two distinct families, the Cheloniidae (hard-shelled sea turtles) and the Dermochelyidae (leatherback sea turtles). Sea turtles in these families are distinguished from one another on the basis of their carapace (upper shell) structure. An important marine resource, sea turtles are of nutritional, economic, and existence (non-use) value to humans. However, over the last few centuries, sea turtle populations throughout the world have declined dramatically as a result of anthropogenic activities such as coastal development, oil exploration, commercial fishing, marine-based recreation, pollution, and over-harvesting (NRC 1990; Eckert 1995).

Sea turtles are highly adapted for life in the marine environment. They are unlike terrestrial and freshwater turtles in that they possess powerful, modified forelimbs (or flippers) that enable them to swim continuously for extended periods of time (Wyneken 1997). Sea turtles have also developed a compact and streamlined body plan that helps to reduce drag while underwater. Additionally, sea turtles have evolved physiological traits and behavioral patterns that allow them to spend as little as 3% to 6% of their time at the water's surface (Lutcavage and Lutz 1997), permitting highly efficient foraging and traveling. Sea turtles often travel thousands of miles between their nesting beaches, mating areas, developmental habitats, and adult feeding grounds; migratory activities which would not be possible without the aforementioned suite of adaptations (Ernst et al. 1994; Meylan 1995). The traits and behaviors of sea turtles also protect them from predation. Sea turtles armor themselves physically by developing a tough outer shell and growing to a large size as adults (Ernst et al. 1994). Mature leatherback sea turtles can weigh over 450 kilograms (kg). Growing to a large size as adults is important because sea turtles cannot withdraw their head or limbs into their shell. As young individuals, sea turtles will evade predation behaviorally by residing in habitats that are either structurally complex or moderately shallow, where predators such as sharks, marine crocodiles, and large fishes do not have easy access (Musick and Limpus 1997).

Although they are specialized for life at sea, sea turtles begin their lives on land. Aside from this brief terrestrial period, which lasts approximately three months as an egg and an additional few minutes to a few hours as a hatchling scrambling to the surf, sea turtles are rarely encountered out of the water. Sea turtles return to land primarily to nest, although certain species in Hawaii return in order to bask while others throughout the world return when injured (Spotila et al. 1997). These activities are infrequent yet often vital to the continued existence of a sea turtle (Musick and Limpus 1997). Sea turtles observed on land are most often females since males are not involved in the nesting process and likely gain fewer benefits from basking on land than females (Spotila et al. 1997). Scientists have determined that females bask not only to thermoregulate and elude predators, but also to avoid harmful mating encounters with male turtles and possibly to accelerate the development of their eggs (Spotila et al. 1997).

Female sea turtles nest in tropical, subtropical, and warm-temperate latitudes, often in the same region where they were born (Miller 1997). Upon selecting a suitable nesting beach, female sea turtles tend to re-nest in relatively close proximity during subsequent nesting attempts. In the Caribbean region nesting occurs year-round. Female sea turtles usually lay several clutches of eggs during a nesting season, with each clutch containing between 50 and 200 eggs, depending upon the species (Witzell 1983; Dodd 1988; Hirth 1997). Most females, with the possible exception of Kemp's ridleys, do not nest in consecutive years, typically skipping two or three years before returning (Márquez-M. 1994; Ehrhart 1995). Nesting success is vital to the long-term existence of sea turtles, as roughly one in every 1,000 sea turtle hatchlings survives long enough to reproduce (Frazer 1986).

During the nesting season, daytime temperatures on tropical, subtropical, and warm-temperate beaches can be lethal. As a result, adult sea turtles often nest and hatchlings often emerge from their nest at night (Miller 1997). After emerging from the nest, sea turtle hatchlings use visual cues (e.g., light intensity or the wavelength of light) to orient themselves towards the sea (Lohmann et al. 1997). Hatchlings have a strong tendency to crawl in the direction of the brightest light, which on most beaches is towards the

ocean/sky horizon (Ernst et al. 1994). Some hatchlings, however, never make it into the water. On the beach, sea turtle hatchlings are easy prey for seabirds during the day and scavenging crabs and mammals at night. Hatchlings can also suffer the effects of disorientation if artificial beachfront lighting appears brighter than the seaward horizon (Lutcavage et al. 1997). Those hatchlings that do make it offshore will spend the first few years of their lives in oceanic waters, drifting in convergence zones and *Sargassum* rafts where they find refuge and food (mostly pelagic invertebrates) in items that accumulate in surface circulation features (Carr 1987). Originally labeled the "lost year," this stage in a sea turtle's life history is now known to be much longer in duration, possibly lasting ten years or more (Chaloupka and Musick 1997; Bjorndal et al. 2000). Post-hatchling sea turtles spend nearly a decade growing in the pelagic "early juvenile nursery habitat" before migrating to distant feeding grounds, which are known as the "later juvenile development habitat" (Musick and Limpus 1997; Eckert and Abreu-Grobois 2001). Shallow nearshore and inshore waters represent the developmental habitat most often utilized by hard-shelled sea turtles. For leatherback sea turtles, however, the developmental habitat can be either a coastal feeding area in temperate waters or an offshore feeding area in tropical waters depending upon the season.

Once in the developmental habitat, most sea turtles modify their foraging behavior from surface to benthic feeding and will begin to feed upon larger items such as crustaceans, mollusks, sponges, coelenterates, fishes, and seagrasses (depending upon the species) (Bjorndal 1997). An exception is the leatherback sea turtle, which will feed on pelagic soft-bodied invertebrates at both the surface and at great depths. Sea turtles do not have teeth, but their jaws have modified "beaks" suited to their particular diet (Mortimer 1995). The diet exhibited by a sea turtle varies according to the habitat in which it feeds and its preferred prey. Sea turtles undergo complex seasonal movements, which are influenced by changes in ocean currents, turbidity, salinity, and food availability. Sea turtles possess a specialized digestive system so that a diverse array of food items can be consumed (Mortimer 1995).

In addition to the above factors, distribution for many sea turtle species is dependent upon (and often restricted by) water temperature (Lutcavage and Musick 1985; Epperly et al. 1995a; Coles and Musick 2000). Most sea turtles become lethargic at temperatures below 10°C and above 40°C (Spotila et al. 1997). Coles and Musick (2000) observed that the range of each species' preferred water temperature regulates sea turtle distribution. The normal range of water temperatures that sea turtles prefer is from 13.3° to 28°C (Coles and Musick 2000). Sea turtles' preferred temperature ranges vary across age classes and species as well as seasons. As a species, leatherback sea turtles have a much wider range of preferred temperatures than other species because they can maintain warm body temperatures in the North Atlantic and can avoid overheating in the tropics (Spotila et al. 1997).

Although sea turtles are nearsighted out of water, their vision underwater is very good. Their sense of smell is also very keen (Ernst et al. 1994), and a sea turtle likely uses olfaction in conjunction with sight during foraging. Sea turtle hearing sensitivity is not well studied. Reception of sound through bone conduction, with the skull and shell acting as receiving structures, is hypothesized to occur in some sea turtle species (Lenhardt et al. 1983). A few preliminary investigations using adult green, loggerhead, and Kemp's ridley turtles suggest that they are most sensitive to low-frequency sounds (Ridgway et al. 1969; Lenhardt et al. 1983; Bartol et al. 1999). An anecdotal observation of a leatherback's response to the sound of a boat motor suggests that leatherbacks may be sensitive to low-frequency sounds, but the response could have been to mid- or high-frequency components of the sound (ARPA 1995).

The range of maximum sensitivity for sea turtles is 100 to 800 Hertz (Hz), with an upper limit of about 2,000 Hz (Lenhardt 1994). Hearing below 80 Hz is less sensitive but still potentially usable to the animal (Lenhardt 1994). Green sea turtles are most sensitive to sounds between 200 and 700 Hz, with peak sensitivity at 300 to 400 Hz. They possess an overall hearing range of approximately 100 to 1,000 Hz (Ridgway et al. 1969). Bartol et al. (1999) reported that juvenile loggerhead sea turtles hear sounds between 250 and 1,000 Hz; however, O'Hara and Wilcox (1990) found that they would often avoid sources of low-frequency sound. Finally, sensitivity even within the optimal hearing range is apparently low—threshold detection levels in water are relatively high at 160 to 200 decibels with a reference pressure of 1 micropascal (dB re 1 μPa-m) (Lenhardt 1994). In terms of sound emission, nesting leatherback sea turtles produce sounds in the 300 to 500 Hz range (Mrosovksy 1972).

For further information on the biology, life history, and conservation of sea turtles, the following organizations' websites are extremely useful: the Archie Carr Center for Sea Turtle Research (http://accstr.ufl.edu/index.html), the Caribbean Conservation Corporation (http://www.cccturtle.org), and seaturtle.org (http://www.seaturtle.org). Other important resources include Proceedings from the Annual Symposium on Sea Turtle Biology and Conservation, Lutz and Musick (1997), and Bjorndal (1995).

3.2.2 Sea Turtles of the PROA/St. Croix OPAREA

Of the seven living species of sea turtle, six have been documented to occur in the wider Caribbean region (Eckert and Abreu-Grobois 2001). These include the leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), and olive ridley (*Lepidochelys olivacea*) sea turtles (Table 3-2). All six species are protected under the ESA. The hawksbill, Kemp's ridley, and leatherback are listed as endangered, while the loggerhead is listed as threatened. As a species, the green and olive ridley sea turtles are also listed as threatened although specific nesting populations are currently listed as endangered. Not all green sea turtles found in the Caribbean, however, are from the Florida population (Bass and Witzell 2000).

Table 3-2. Sea turtle species potentially occurring in the PROA/St. Croix OPAREA and vicinity. Taxonomy follows Pritchard (1997).

	Scientific Name	Status
Order Testudines (turtles)		
Suborder Cryptodira (hidden-necked turtles)		
Family Dermochelyidae (leatherback sea turtle)		
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Family Cheloniidae (hard-shelled sea turtles)		
Green sea turtle	*Chelonia mydas*	Threatened[a]
Hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Olive ridley sea turtle	*Lepidochelys olivacea*	Threatened[b]

[a] As a species, the green sea turtle is listed as threatened. However, the Florida and Mexican Pacific coast nesting populations are listed as endangered. It should be noted that only a fraction of green sea turtles found in the PROA/St. Croix OPAREA and vicinity come from the Florida population.

[b] As a species, the olive ridley sea turtle is listed as threatened. However, the Mexican Pacific coast nesting population is listed as endangered.

Puerto Rico and the Virgin Islands provide critical nesting, foraging, and developmental habitat for three species of sea turtle: the leatherback, green, and hawksbill (Hillis-Starr et al. 1998). The loggerhead has also been documented to occur in the waters surrounding these islands but on infrequent occasions (Rainey 1979). The waters around Puerto Rico and the Virgin Islands are attractive to sea turtles because they are warm year-round, they provide a diverse mosaic of feeding habitats (from shallow coral reefs and seagrass beds to deep water trenches), and they provide easy access to suitable nesting beaches.

All available sea turtle sighting (aerial and ship survey), stranding, incidental fisheries bycatch, nest, and track occurrence records (Appendix A, Table A-2) were used to predict the spatial and temporal occurrences of the six sea turtle species that may occur in the vicinity of the PROA/St. Croix OPAREA. The occurrence records from the ship surveys were strictly opportunistic as these surveys were dedicated marine mammal surveys and the sightability of sea turtles from ships is low. An occurrence record, regardless of its source, does not reflect the number of sea turtles as multiple individuals of a species are

often sighted at the same time at the same location. Therefore, the occurrence records shown on the map figures that accompany this section represent the number of data records collected, not the number of sea turtles observed. The process by which the occurrence predictions and map figures were created is described in detail in Section 1.4.2.2.

The occurrence of sea turtles in the PROA/St. Croix OPAREA may vary seasonally (winter=January through March; spring=April through June; summer=July through September; fall=October through December). It should be noted that the number of sea turtle occurrence records in a given area is often as much a function of the source or type of data (aerial or shipboard sighting records versus stranding records), level of effort, and sighting conditions (such as calm seas) as the actual abundance of sea turtles in that area. The greatest number of sea turtle occurrences within the PROA/St. Croix OPAREA grid blocks from sighting, stranding, and fisheries bycatch records were found in summer and fall (501 and 341, respectively; Appendix C, Table C-1), undoubtedly as a result of greater survey effort and better sighting conditions during these seasons. Fewer occurrences were recorded during winter and spring (61 and 254, respectively; Table C-1) when survey effort was lower and sighting conditions were less than optimal. For each season, however, no more than three sea turtle species were recorded within the OPAREA.

On the map figures, various types of shading and terminology designate the occurrence of sea turtles in the PROA/St. Croix OPAREA. “Expected occurrence” (area shaded in light blue) is defined as the area encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and the available sighting, stranding, nest, and track data. “Concentrated occurrence” (area shaded in dark blue) is the subarea of a species' expected occurrence where there is the highest likelihood of encountering that species; the designation is based primarily on areas of concentrated sightings and preferred habitat. “Low/unknown occurrence” (pattern-filled area) is the area where the likelihood of encountering a species is rare or not known. It should be noted that, for any given area, a description of sea turtles known to occur in that area is as much a function of survey type (beach survey, stranding data collection, aerial or shipboard survey) and level of effort and sighting conditions (such as calm seas) as actual animal occurrences. “Occurrence not expected,” (white, unmarked area) indicates the area where a species encounter is not expected.

Sea turtles are expected to occur throughout the PROA/St. Croix OPAREA during all seasons (Appendix C, Figure C-1) due to the preference of shallow benthic habitats by green and hawksbill sea turtles and the preference of deeper pelagic habitats by leatherback sea turtles. Sea turtles concentrate year-round in the waters surrounding Culebra, PR; Vieques, PR; Buck Island, USVI; and eastern St. Croix, USVI, as well as along the east coast of Puerto Rico near from Naval Station Roosevelt Roads south to Humacao (Hillis-Starr et al. 1998; Eckert and Abreu-Grobois 2001; Fleming 2001). They also will concentrate in the waters around Sandy Point, St. Croix, USVI but only during the spring and summer, as a result of leatherback sea turtles coming from great distances to nest over a four-month period (Eckert and Eckert 1983; Boulon et al. 1996; Fleming 2001).

- Leatherback Sea Turtle (*Dermochelys coriacea*)

  Description—The leatherback is the largest living sea turtle. These sea turtles are placed in the family Dermochelyidae, a separate family from all other sea turtles, in part because of their unique carapace structure. The carapace lacks the outer layer of horny scutes possessed by all other sea turtles; it is instead composed of a flexible layer of dermal bones underlying tough, oily connective tissue and smooth skin. The body is barrel-shaped and tapered to the rear, with seven longitudinal dorsal ridges, and is almost completely black with variable spotting. Every adult leatherback possesses a unique spot on the dorsal surface of its head, a marking that can be used by scientists to identify specific individuals (McDonald and Dutton 1996). Adult carapace lengths range from 130 to 180 centimeters (cm) (NMFS and USFWS 1992), with a maximum of 256.5 cm (Ernst et al. 1994).

  Status—Leatherback sea turtles are classified as endangered under the ESA. There are an estimated 20,000 to 30,000 leatherbacks in the North Atlantic Ocean (Coren 2000). The worldwide population of leatherbacks in 1995 was approximately 34,500 nesting females, with confidence limits

of 26,200 to 42,900 (Spotila et al. 1996). Nesting populations using the beaches of southern Florida, Culebra, and St. Croix are believed to be increasing due to heightened protection and monitoring of the nesting habitat over the past twenty years (Hillis-Starr et al. 1998; Fleming 2001; FMRI 2002).

Habitat Preferences—Adult leatherback sea turtles are known to range from mid-ocean to the continental shelf and nearshore waters (Schroeder and Thompson 1987; Shoop and Kenney 1992; Grant and Ferrell 1993; Epperly et al. 1995a, 1995b). The distributions and movements of these turtles appear to be linked to the seasonal availability of their prey and the requirements of their reproductive cycle (Collard 1990a; Davenport and Balazs 1991). Critical habitat for the leatherback sea turtle includes the waters adjacent to Sandy Point, St. Croix (the largest leatherback rookery under U.S. jurisdiction) out to 183 meters (m) in depth with boundaries at 17°42'12"N and 64°50'00"W (Eckert and Eckert 1983; Boulon et al. 1996; Fleming 2001; NMFS 2001) (Figure 3-2).

Distribution—The leatherback sea turtle is distributed circumglobally in tropical and warm-temperate waters throughout the year and into cooler temperate waters during warmer months (Ernst et al. 1994). Leatherbacks in the North Atlantic are broadly distributed from the Caribbean region to as far north as Nova Scotia, Newfoundland, Labrador, Iceland, the British Isles, and Norway (Ernst et al. 1994). This species migrates further and moves into cold waters more than any other sea turtle species (Bleakney 1965; Lazell 1980; Shoop and Kenney 1992). This species is also the most oceanic and most wide-ranging of sea turtles, undertaking extensive migrations following depth contours for hundreds, even thousands, of kilometers (Morreale et al. 1996; Hughes et al. 1998). Using satellite telemetry, it was determined that female leatherback turtles migrating through the Pacific Ocean are using similar, and in some cases virtually identical, pathways or ocean corridors through which to travel (Morreale et al. 1996).

In the western North Atlantic, leatherbacks show strong seasonal distribution patterns and extensive migrations. Tag returns from individuals tagged at tropical nesting beaches have documented some of the longest migrations of any reptile (Meylan 1995). Female turtles tagged in the USVI, Colombia, French Guiana, and Costa Rica have been found stranded along the Atlantic and Gulf coasts of the U.S. (Thompson et al. 2001). One leatherback caught in the Chesapeake Bay was tagged, released, and then caught again over a year later off southern Cuba, a minimum distance of 2,168 kilometers (km) (Keinath and Musick 1990). Tagging studies also indicate many variations in overwintering and onshore-offshore occurrence patterns (Lee and Palmer 1981). For example, a leatherback satellite-tagged at a nesting beach in Florida traveled to Virginia, staying within 100 km of shore, and spent four months in the area (CCC 2002).

The seasonal occurrence of large subadult and adult leatherbacks off the Atlantic coast of the U.S. and Canada appears to vary with latitude. Aerial survey results along the western North Atlantic coast of North America suggest there are seasonal movements of large juvenile to adult-sized leatherbacks from the southeastern coast in the spring to the mid-Atlantic, New England, and Canadian coastal waters in the summer (CETAP 1982; Shoop and Kenney 1992; Thompson et al. 2001). The number of strandings correlates with the seasonal occurrences in these areas (Thompson et al. 2001). Monthly sighting frequencies are highest along the northeastern U.S. between June and October, with a maximum in September (Shoop and Kenney 1992). Two areas of high summer abundance occur in the northeastern U.S.: south of Long Island and in the central and eastern Gulf of Maine (Shoop and Kenney 1992). In North Carolina, the leatherback sea turtle usually occurs from mid-April through mid-October in relatively shallow waters (Lee and Palmer 1981; Keinath et al. 1996). The coastal area immediately adjacent to Cape Hatteras has long been recognized as a migratory pathway for leatherbacks (Lee and Palmer 1981; NRDC 2000).

Nesting beaches used by leatherbacks in the western North Atlantic are restricted to the tropics (NMFS and USFWS 1992). Nesting occurs along the coasts of South, Central, and North America from Brazil to Mexico and throughout the West Indies, with significant populations in French Guiana, Surinam, and Costa Rica (Ernst et al. 1994). In the eastern Caribbean, leatherback sea turtles nest annually on beaches in northern Puerto Rico, Culebra, Vieques, and St. Croix (Hillis-Starr et al. 1998). Leatherbacks prefer to nest on open sand beaches that are backed with vegetation, are

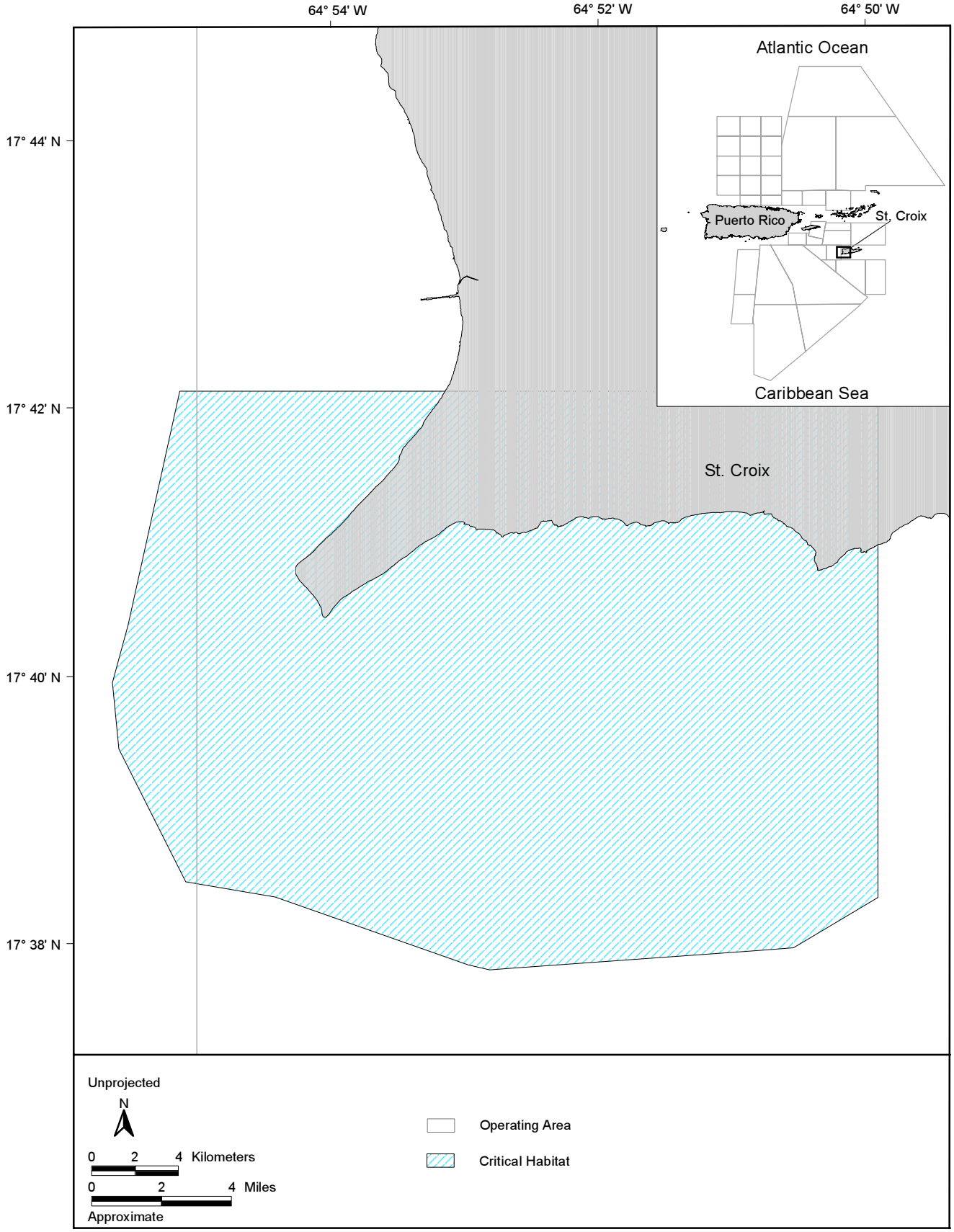

Figure 3-2. Critical habitat for leatherback sea turtles. Critical habitat includes waters adjacent to Sandy Point, St. Croix, USVI up to and inclusive of the waters from the mean high water line to 183 m in depth with boundaries at 17°42'12"N and 64°50'00"W. Source information: NMFS (2001).

sufficiently inclined, and are in close proximity to deep water (DoN 2001). Once the nesting season is over, most leatherbacks in the Caribbean leave the tropics for feeding grounds further north.

- Information Specific to PROA/St. Croix OPAREA—The available leatherback sea turtle sighting, stranding, nest, and track data indicate that this species is most common in the waters of the Puerto Rico Platform during spring and summer, the time of year when nesting activity peaks (Figure C-2). Leatherback occurrence during these two seasons is concentrated in the waters surrounding Sandy Point, St. Croix and Culebra, as these two areas experience the highest rates of leatherback nesting in the PROA/St. Croix OPAREA region (Fleming 2001). Since leatherbacks only enter the shallow waters of the Caribbean region during the nesting season, the occurrence of this species on the continental shelf is low/unknown during fall and winter (Hillis-Starr et al. 1998).

  For all seasons, the waters of the PROA/St. Croix OPAREA beyond the continental shelf break are labeled as areas of expected occurrence. This is due to the leatherback's affinity for extremely deep water and the possibility that these waters serve as early juvenile nursery habitat for leatherbacks that hatch on beaches in the Greater and Lesser Antilles. Leatherback sea turtles likely venture through the deepest waters of the OPAREA on their way to and from the nesting beach, as well as during inter-nesting intervals (the period of time between successive nesting events) (Figure 3-3).

Behavior and Life History—The wider range of leatherbacks when compared to other sea turtles is likely due to their highly evolved thermoregulatory capabilities. Leatherbacks can maintain body core temperatures well above ambient. For example, a leatherback caught off Nova Scotia had a body temperature of 25.5°C in water that was 7.5°C (Frair et al. 1972). A variety of studies have shown that leatherbacks have a range of anatomical and physiological adaptations that enable them to regulate internal body temperatures (Mrosovsky and Pritchard 1971; Greer et al. 1973; Neill and Stevens 1974; Paladino et al. 1990).

Leatherback sea turtles predominantly feed upon gelatinous zooplankton such as jellyfish and salps (Bjorndal 1997); however, a wide variety of other prey items are known (NMFS and USFWS 1992). In the North Atlantic Ocean, the primary prey appears to be the lion's-mane or arctic jellyfish (Lazell 1980). Leatherbacks feed throughout the water column from the surface to depths as far as 1,200 m (Eisenberg and Frazier 1983; Davenport 1988). Studies of leatherback sea turtle diving patterns off St. Croix suggested that nocturnal foraging on the deep-scattering layer was taking place (S. Eckert et al. 1989).

Mating is thought to occur prior to or during the migration from temperate to tropical waters (Eckert and Eckert 1988). Typical clutches range in size from 50 to over 150 eggs, with the incubation period lasting around 65 days. Females lay an average of five to seven clutches in a single season (with a maximum of 11) at 8- to 10-day intervals or longer (NMFS and USFWS 1992). Females remain in the general vicinity of the nesting habitat during inter-nesting periods, with total residence in the nesting/inter-nesting habitats lasting up to four months (K. Eckert et al. 1989; Keinath and Musick 1993). Most adult females return to nest on their natal beach every two years; however, remigration intervals (the number of years between successive nesting seasons) between one and five years have been recorded (Boulon et al. 1996). The nesting season of the western North Atlantic leatherback stock is mainly from March to July (NMFS and USFWS 1992).

The leatherback is the deepest diving sea turtle. Dive depth likely depends on the reason for the dive and the proximity to shore; leatherbacks closer to shore probably make shallower dives than those in the open ocean (Ernst et al. 1994). Average dive depths from tagging studies off the continental shelf of St. Croix are 35 to 122 m, with estimated maximum depths of over 1,000 m (S. Eckert et al. 1989). Typical dive durations average 6.9 to 14.5 minutes (min) per dive, with a maximum of 42 min (Eckert et al. 1986; S. Eckert et al. 1989). Routine dive lengths for leatherbacks around St. Croix can range from 4 to 14.5 min. Day dives around St. Croix were deeper and longer than those at night. Eckert et al. (1996) described leatherback sea turtle diving off Malaysia, where the bottom depth barely

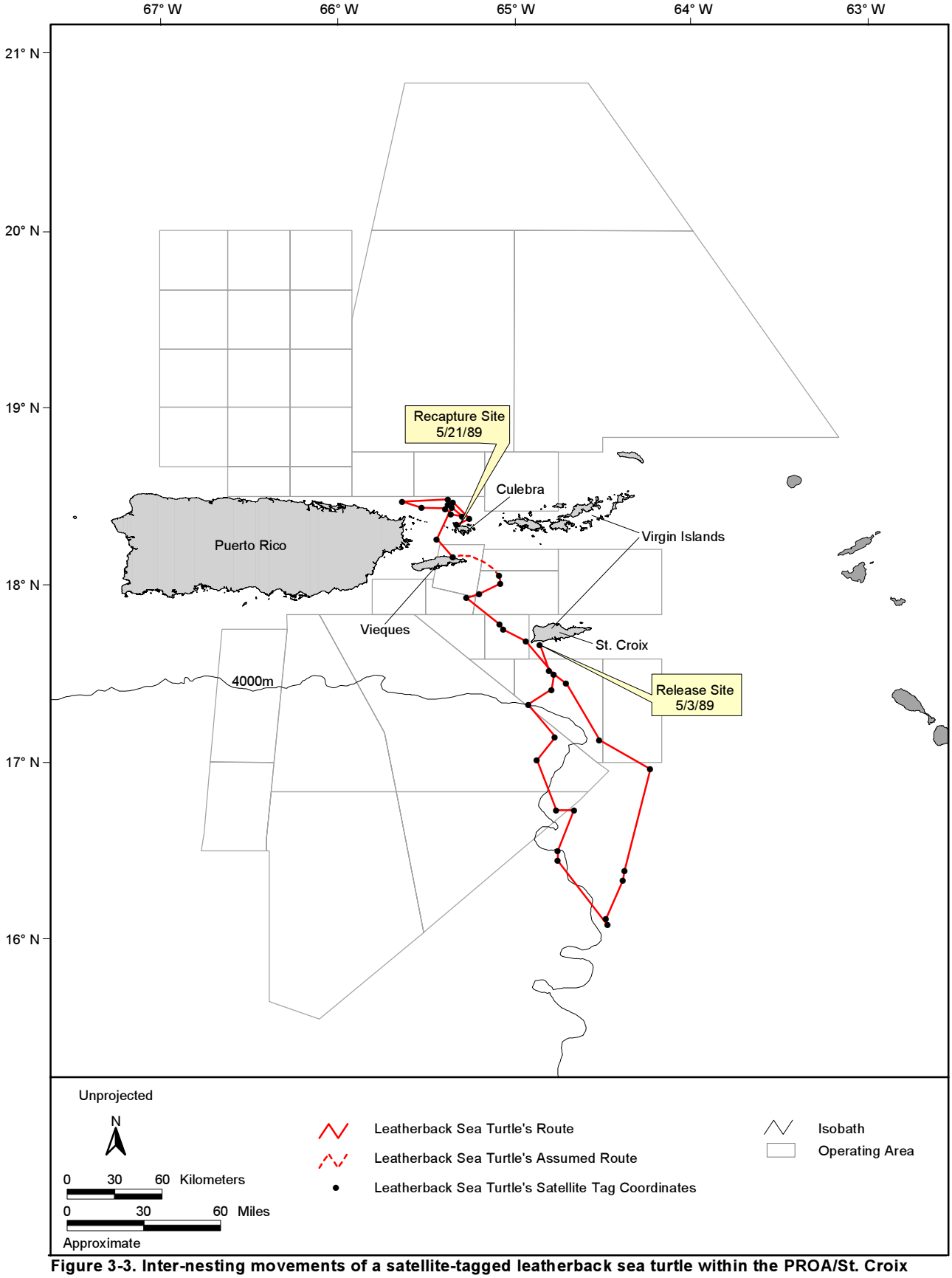

Figure 3-3. Inter-nesting movements of a satellite-tagged leatherback sea turtle within the PROA/St. Croix OPAREA from 3 through 21 May 1989. Over this 19-day period the adult female nested at Sandy Point, St. Croix, USVI; on the northern shore of Vieques, PR; and on Culebra, PR. Map adapted from: Keinath and Musick (1993).

reaches 60 m. Bottom times were greater than 3 min in 47% of all dives in this shallow-water habitat. Standora et al. (1984) measured a maximum dive length of 7.7 min for a subadult leatherback.

- Green Sea Turtle *(Chelonia mydas)*

Description—The green sea turtle is the largest hard-shelled sea turtle in the Atlantic; adults commonly reach 100 cm in carapace length (NMFS and USFWS 1991a). Adult carapaces range in color from solid black to gray, yellow, green, and brown in muted to conspicuous patterns; the plastron is a much lighter yellow to white. Hatchlings are distinctively black on the dorsal surface and white on the ventral.

Status—Green sea turtles worldwide are classified as threatened, with the Florida and Mexican Pacific coast nesting populations listed as endangered under the ESA (NMFS and USFWS 1991a). There is no estimate of the total number of green sea turtles in the North Atlantic Ocean.

Habitat Preferences—"Lost year" green sea turtles are believed to reside in oceanic waters for a period of three to seven years (Balazs 1999). Once they reach a carapace length of 20 to 25 cm, greens then migrate to shallow nearshore areas where they spend the majority of their lives as late juveniles and adults (NMFS and USFWS 1991a; Ernst et al. 1994; Bjorndal and Bolten 1998). In laboratory experiments, Mellgren et al. (1994) found that hatchling green turtles did not orient to or congregate in artificial weed beds or in real seaweeds. They concluded that the "lost year" habitat of the green sea turtle has yet to be determined, although Carr and Meylan (1980) present direct evidence of hatchlings taking refuge in and around *Sargassum* rafts.

The optimal habitats for benthic-stage juveniles and adults are warm waters that (1) are quiet and shallow, (2) possess an abundance of submerged vegetation (seagrasses and/or algae), and (3) are located in close proximity to nearshore reefs or rocky areas that are used for resting (Ernst et al. 1994). Green sea turtles will feed as deep as their primary food source will grow (Bjorndal personal communication). In Hawaii, green sea turtles have been found foraging in waters as deep as 20 to 50 m (Brill et al. 1995).

Critical habitat for the green sea turtle includes the waters surrounding Culebra out to 3 NM (5.6 km) (NMFS 1998) (Figure 3-4). These waters are known to harbor a large population of juvenile and subadult greens, which use the area as a developmental feeding habitat (Collazo et al. 1992).

Distribution—Green sea turtles are distributed circumglobally in tropical and sub-tropical waters (Ernst et al. 1994). In U.S. Atlantic waters, greens are found around the U.S. Virgin Islands, Puerto Rico, and the continental U.S. from Texas to Massachusetts (NMFS and USFWS 1991a). Adults are predominantly tropical and are only occasionally found north of Florida. Most sightings of individuals north of Florida are of subadults during the warmest parts of the year (Lazell 1980; CETAP 1982; Burke et al. 1992; Epperly et al. 1995b). Small numbers of immature greens regularly occur as far north as Long Island, New York (Morreale et al. 1992). Long Island's waters are warm enough to support green sea turtles from June through October (Morreale et al. 1992). Individuals avoid becoming cold-stunned by moving from these waters prior to the onset of winter.

Adult green sea turtles are known to undertake long oceanic migrations between nesting and foraging habitats. As they grow, most greens move through a series of developmental feeding habitats, which are often separated by thousands of miles (Hirth 1997). Green sea turtles have been seen in the open ocean more than 1,600 km from land (Fritts et al. 1983) and can likely traverse an entire ocean basin during their life cycle (Eckert and Abreu-Grobois 2001). However, since these animals often feed in shallow waters with an abundance of submerged vegetation, most individuals choose to travel close to shore (Ernst et al. 1994).

The major Atlantic nesting colonies are located at Aves Island, Venezuela (in the Caribbean Sea, about 180 km west of Guadaloupe) and on the beaches of Costa Rica and Suriname (in central and

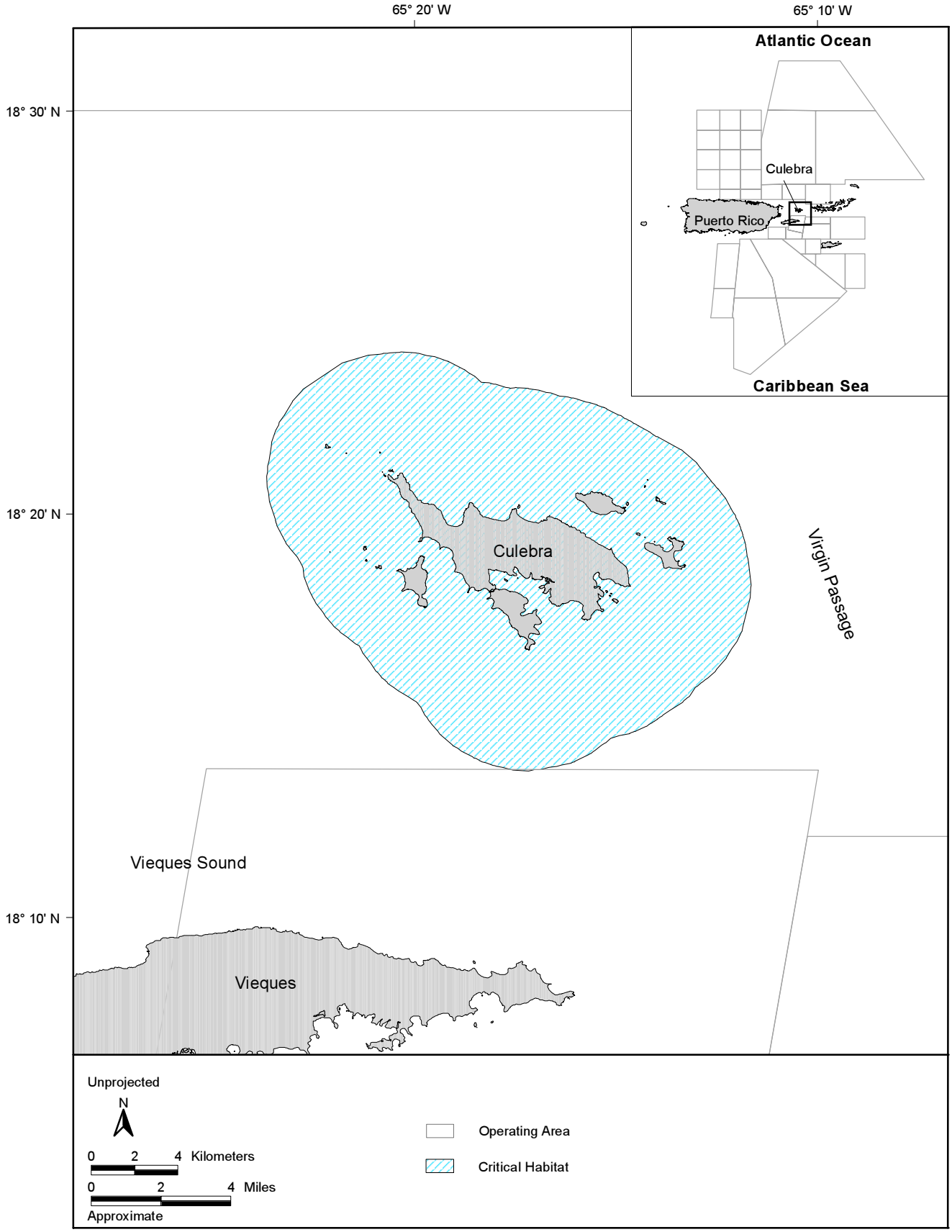

Figure 3-4. Critical habitat for green sea turtles. Critical habitat extends 3 NM (5.6 km) seaward from the mean high water line of Culebra, PR. Source information: NMFS (1998).

South America, respectively) (NMFS and USFWS 1991a). Most nesting in North America occurs in southeast Florida and Mexico (Meylan et al. 1995), with scattered records in Georgia and the Carolinas (Peterson et al. 1985; Schwartz 1989; NMFS and USFWS 1991a). Green sea turtles rank second behind loggerheads in the number of nests laid on U.S. beaches per year (Dodd 1995; Meylan et al. 1995). Mixed-stock analyses on foraging populations of juvenile green sea turtles have revealed that developmental feeding habitats likely contain sea turtles from multiple stocks. Green sea turtles occurring on Caribbean foraging grounds include representatives from the Costa Rican, U.S., Mexican, Aves Island, Suriname, Ascension Island, and Guinea Bissau (west African) stocks (Lahanas et al. 1998).

- Information Specific to PROA/St. Croix OPAREA—Based on the sighting data and habitat preferences of this species, the green sea turtle is expected to occur along the continental shelf and shelf edge of the Puerto Rico Platform during all seasons (Figure C-3). Juvenile and subadult green turtles are known to forage throughout the coastal areas surrounding Puerto Rico and the Virgin Islands (Hillis-Starr et al. 1998), utilizing seagrass bed habitats for feeding and coral reef habitats for resting (refer to Figures 4-2 and 4-3). Dense aggregations of green sea turtles are known to inhabit the waters surrounding Culebra, Vieques, and Naval Station Roosevelt Roads (Rathbun et al. 1985; Collazo et al. 1992; DoN 2001). These areas of concentrated occurrence not only coincide with areas where sightings are frequent, but they also coincide with areas where extensive seagrass beds are known to exist. Smaller, but still significant, foraging populations are known to reside along the northern coast of Puerto Rico (Rathbun et al. 1985), the southern and eastern coast of St. Thomas (Vicente and Tallevast 1995), and the eastern end of St. Croix (Ogden et al. 1983).

  Waters of the PROA/St. Croix OPAREA that are too deep to promote growth of both seagrasses and coral reefs are designated as areas of low/unknown occurrence during all seasons. The occurrence of greens in waters far past the shelf break is also low/unknown as a result of low survey effort in these areas. Green sea turtle hatchlings, juveniles, and adults, however, may be present in deep waters while in transit to nursery, developmental, or nesting habitats. Several immature green sea turtles tagged in the U.S. Virgin Islands were later recaptured as far away as the Bahamas, the Grenadines, and the Dominican Republic (Boulon 1989).

Behavior and Life History—Adult green sea turtles feed on submerged seagrasses (e.g., turtle grass, manatee grass, and shoal grass) and algae (Burke et al. 1992; Ernst et al. 1994; Bjorndal 1997). Hatchlings and juveniles are more omnivorous, feeding on a variety of invertebrates and fishes as well (Ernst et al. 1994). Observations of foraging adult green sea turtles in Hawaiian waters suggest that when individuals feed, they generally lie down on the sea bottom and then crawl or move to a nearby site when food is no longer within easy reach (Hochscheid et al. 1999).

Green sea turtles are estimated to take 27 to 50 years to reach sexual maturity, the longest age to maturity for any sea turtle species (Frazer and Ehrhart 1985). Mature females nest from one to seven times in a season (two to three is typical) at approximately two-week intervals, and reproduce every two to four years (NMFS and USFWS 1991a). Within a nesting season, the female remains in close proximity to the nesting beach during the inter-nesting intervals (Meylan 1995). Between 110 and 145 eggs are laid at a time, and the incubation period is 50 to 60 days. In the Caribbean, green sea turtle nesting peaks from June to August, although in Puerto Rico it is known to occur as early as March (Hall 1994).

Green sea turtles typically make dives shallower than 30 m (Hochscheid et al. 1999; Hays et al. 2000); however, a maximum dive depth of 110 m has been recorded in the Pacific Ocean (Berkson 1967). The maximum dive time recorded for a subadult green sea turtle is 66 min, with routine dives ranging from 9 to 23 min (Brill et al. 1995).

- Hawksbill Sea Turtle (*Eretmochelys imbricata*)

Description—The hawksbill sea turtle is a small to medium-sized sea turtle, with an adult carapace length of 65 to 90 cm (Witzell 1983). Hawksbills are distinguished from other sea turtles on the basis of their hawk-like beaks, posteriorly overlapping carapace scutes, and two pairs of claws on their flippers.

Status—Hawksbill sea turtles are classified as endangered under the ESA and are second only to the Kemp's ridley in terms of endangerment (NMFS and USFWS 1993; Bass 1994). Hawksbill populations in the western Atlantic-Caribbean region are considered as greatly depleted and only remnants of much larger aggregations in the past. The most recent estimate of hawksbill abundance in the wider Caribbean was 4,975 nesting females calculated by Meylan in 1989 (Meylan and Donnelly 1999). In U.S. waters, hawksbill populations are noted as neither declining nor showing indications of recovery (Plotkin 1995). Only five regional populations worldwide remain with more than 1,000 females nesting annually (Seychelles, Mexico, Indonesia, and two in Australia) (Meylan and Donnelly 1999).

Habitat Preferences—Hawksbills inhabit oceanic waters as hatchlings and small juveniles, where they are sometimes associated with floating patches of *Sargassum* (Parker 1995). Larger juveniles and adults inhabit shallow nearshore feeding areas in the tropics associated with coral reefs, mangroves, or other hard bottom habitats. Adults may occupy somewhat deeper waters (to 24 m) than juveniles (to 12 m) (NMFS and USFWS 1993).

Critical habitat for the hawksbill sea turtle includes the waters surrounding Mona Island, PR out to 3 NM (5.6 km) (NMFS 1998) (Figure 3-5). The waters surrounding Mona and Monito Islands provide suitable habitat for both nesting females and foraging juveniles (Diez and van Dam 1996; Diez et al. 1996). Using molecular data, Bowen et al. (1996) showed that the hawksbill foraging population surrounding Mona Island was largely composed of sea turtles from several distant rookeries.

Distribution—Juvenile and adult hawksbills are found throughout the Gulf of Mexico, Caribbean, and along the Atlantic coast of southern Florida, rarely venturing as far north as New England (Lazell 1980; Witzell 1983; NMFS and USFWS 1993). Originally thought to be a non-migratory species, due to the close proximity of suitable nesting beaches to coral reef feeding habitats and high rates of local recapture, hawksbills are now known to travel long distances over the course of their lives (Meylan 1999a). Tag return, genetic, and telemetry studies have all indicated that Caribbean hawksbill sea turtles utilize multiple developmental habitats as they progress from age-class to age-class. However, within a given life stage, such as the later juvenile stage, some hawksbills choose to be sedentary within a specific developmental habitat for a long period of time (Meylan 1999a). Hawksbills tend to nest in multiple, small, scattered colonies, with the most significant nesting in the western North Atlantic occurring along the Yucatan Peninsula, Mexico. An estimated 1,900 to 4,300 adult females comprise the Mexican Atlantic nesting population (Garduño et al. 1999).

- Information Specific to PROA/St. Croix OPAREA—As indicated by the available sighting data and the primary literature on this species, the hawksbill, like the green sea turtle, also tends to forage throughout the coastal areas surrounding Puerto Rico and the Virgin Islands. As a result of their preference for nearshore feeding areas, hawksbills are expected to occur during all seasons in continental shelf and shelf edge waters where coral reef and hard bottom habitats are prevalent (refer to Figures 4-2 and 4-3). Areas of concentrated occurrence include the waters surrounding Culebra, Vieques, Buck Island, the eastern end of St. Croix, and the southeastern coast of Puerto Rico near Humacao (Figure C-4). After Mona Island, which is west of the PROA/St. Croix OPAREA, these areas are the next most important in terms of suitable habitat for both adult nesting and juvenile foraging (Hillis and Phillips 1996; Starbird et al. 1999; Fleming 2001). Puerto Rican beaches produce an estimated 650 hawksbill nests each year, while the beaches of Buck Island and the east end of St. Croix are expected to produce an additional 400 nests per year (Plotkin 1995). The majority of these nests are located on beaches lying adjacent to the areas of concentrated occurrence (Meylan 1999b).

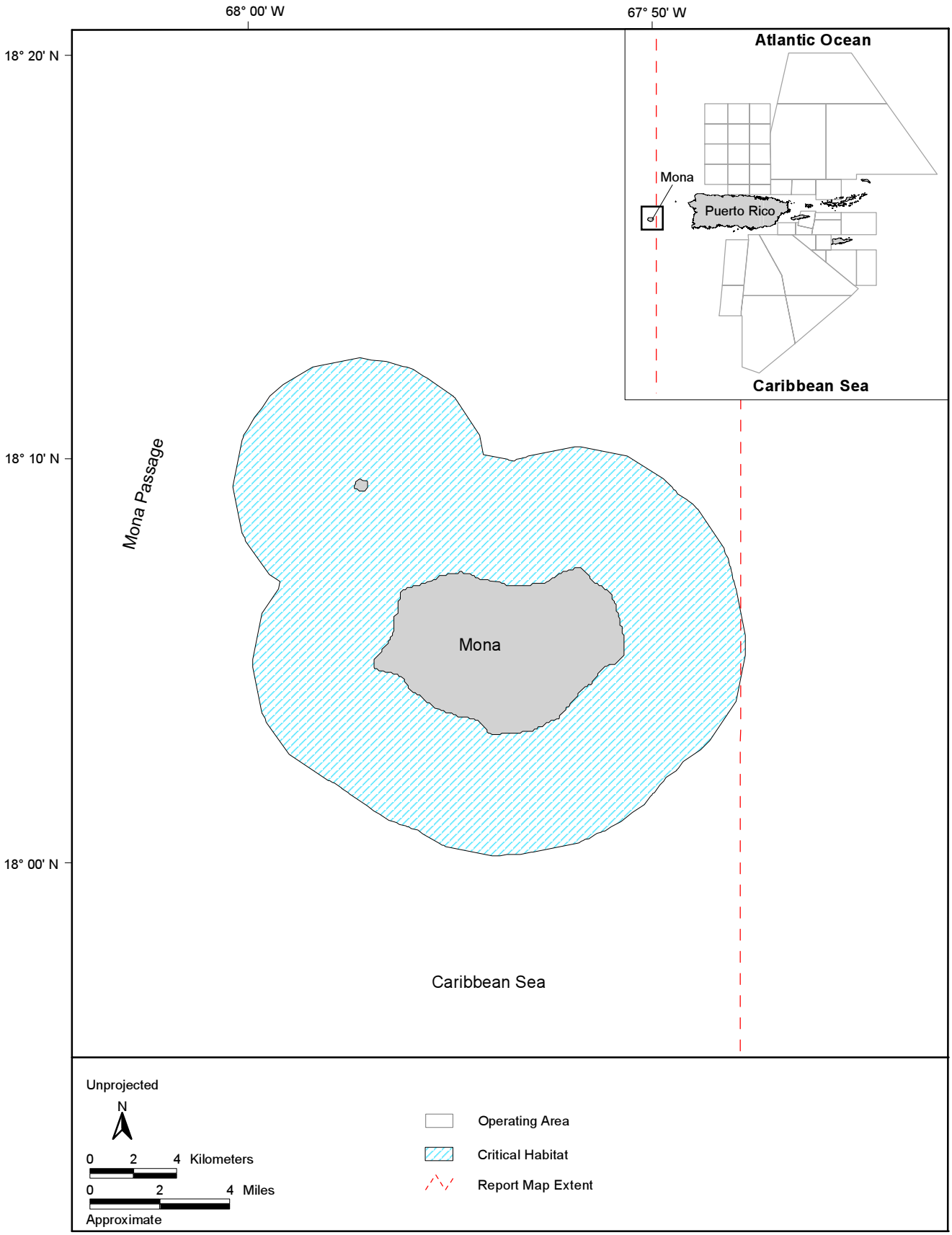

Figure 3-5. Critical habitat for hawksbill sea turtles. Critical habitat extends 3 NM (5.6 km) seaward from the mean high water line of Mona Island, PR. Source information: NMFS (1998).

In deeper waters, where coral reefs and hard bottom substrate are scarce and survey effort is low, the occurrence of hawksbill sea turtles is low/unknown. However, hawksbills are known to make long-distance migrations throughout the Caribbean region. Adult and immature hawksbills tagged at Buck Island, St. Croix, and St. Thomas, USVI have been recaptured in waters off of Cuba, Nicaragua, the Dominican Republic, St. Lucia, St. Martin, and even Venezuela (Boulon 1989; Groshens and Vaughan 1994; Hillis 1994).

Behavior and Life History—Hatchlings and small juveniles are believed to utilize *Sargassum* habitat but little is known about their diets during this stage. Hawksbill sea turtles recruit to benthic feeding habitats, such as coral reefs and other hard bottom habitats, at 20 to 25 cm (Meylan 1988). Scientists believe that hawksbills are omnivorous at that stage, feeding on encrusting organisms such as sponges, tunicates, bryozoans, algae, mollusks, and a variety of other items such as crustaceans and jellyfish (Bjorndal 1997). Larger juveniles and adults are more specialized, feeding primarily on sponges, which comprise as much as 95% of their diet in some locations (Witzell 1983; Meylan 1988).

The nesting season of hawksbills is the longest of all sea turtles; nesting may occur year-round. In the western North Atlantic nesting occurs primarily between spring and late fall, with a peak in nesting activity between July and October (Witzell 1983). Mating is believed to take place in the waters adjacent to the nesting beach. Nesting occurs on both low- and high-energy beaches in tropical latitudes. Adult female nesting is often nocturnal and usually occurs on beaches with sufficient vegetative cover. An individual female nests two to five times per season with an inter-nesting interval of about 14 to 16 days. The typical remigration interval is two to three years. Clutch sizes are relatively large at 140 to 180 eggs, and incubation time is 50 to 61 days.

Hawksbills may have one of the longest routine dive times of all the sea turtles. Starbird et al. (1999) reported that inter-nesting females at Buck Island averaged 56.1 min dives with a maximum dive time of 73.5 min. Mean surface time was about 2 min. Average dives during the day ranged from 34 to 65 min, while those at night were between 42 and 74 min. The movements of all the turtles studied were confined to an area less than 1.5 square kilometers (km^2). Data from time-depth recorders have indicated that foraging dives of immature hawksbills in Puerto Rico range from 8.6 to 14 min in duration and have a mean depth of 4.7 m (van Dam and Diez 1996). These individuals were found to be most active during the day and mostly inactive at night.

- Loggerhead Sea Turtle (*Caretta caretta*)

Description—Loggerheads are large, hard-shelled sea turtles. The mean straight carapace length of adult southeastern U.S. loggerheads is approximately 92 cm (NMFS and USFWS 1991b). Loggerhead sea turtles have substantially larger heads for a given size than other sea turtles. Adults and subadults are mainly reddish-brown in color on top and yellowish-colored underneath.

Status—Loggerhead sea turtles are classified as threatened under the ESA. There is no estimate of the size of the loggerhead population in the western North Atlantic (Frazer 1998). The south Florida nesting subpopulation is the largest loggerhead rookery in the Atlantic Ocean (approximately 83,400 nests in 1998) and is the second largest in the world (TEWG 2000). Nesting trends indicate that the number of nesting females associated with the south Florida subpopulation is increasing (Epperly et al. 2001). However, environmental groups have recently petitioned for both the northern and Florida panhandle nesting subpopulations to be re-designated from threatened to endangered status due to continually decreasing numbers of nesting females over the past decade (TIRN 2002).

Habitat Preferences—The loggerhead sea turtle occurs worldwide in habitats ranging from coastal estuaries to waters far beyond the continental shelf (Dodd 1988). Loggerheads are primarily oceanic as post-hatchlings and early juveniles, often occurring in Sargassum drift lines where they are transported throughout the ocean by dominant currents (Carr 1987; Witherington 1994a; Bolten and Balazs 1995). In the North Atlantic Ocean, it is hypothesized that during the “lost year,” early juvenile loggerheads inhabit the pelagic zone of the North Atlantic Gyre system (Carr 1987). Immature pelagic

loggerheads apparently shift to a different mid-water feeding habitat; in the eastern North Atlantic the mid-water habitat is believed to be the waters surrounding the Azores and Madeira (Brongersma 1972; Bolten et al. 1994; Bolten et al. 1998). After reaching a certain size, early juvenile loggerheads will then make a trans-oceanic crossing back towards the western Atlantic (Musick and Limpus 1997). As adults, subadults, and late juveniles, loggerheads most often occur on the U.S. Atlantic continental shelf and shelf-edge as well as in coastal estuaries and bays (CETAP 1982; Shoop and Kenney 1992).

Developmental habitat for loggerheads includes lagoons, bays, river mouths, and coastal waters typically less than 100 m deep (TEWG 1998). Based on growth models, it is hypothesized that loggerhead subadults occupy coastal feeding grounds for 20 years before their first reproductive migration (Bjorndal et al. 2001).

Musick and Limpus (1997) hypothesized that juvenile loggerheads in the Atlantic and Pacific Oceans inhabit mid-oceanic regions far from the continental shelf, where they use the predominant ocean gyres to assist in their migrations. Loggerheads in the Pacific Ocean have been observed feeding on prey items that tend to aggregate along convergence fronts (Polovina et al. 2000). In the northwestern Atlantic Ocean, the Gulf Stream current has a considerable influence on loggerhead sea turtle distribution (Hoffman and Fritts 1982; Thompson 1984; Chester et al. 1994; Epperly et al. 1995c). This species appears to actively avoid the Gulf Stream in fall to prevent being transported northward but seeks areas where warm waters are associated with the western wall of the Gulf Stream (Hoffman and Fritts 1982; Thompson 1984; Chester et al. 1994; Epperly et al. 1995c). Coles and Musick (2000) identified an upper (28°C) and lower (13.3°C) thermal limit as preferred sea surface water temperatures for loggerhead sea turtles off North Carolina.

Distribution—Loggerhead sea turtles are found in subtropical and temperate waters throughout the world (NMFS and USFWS 1991b). The loggerhead is the most abundant sea turtle occurring in U.S. waters, numbering in the thousands throughout inner continental shelf waters from Cape Cod, MA to southern Florida. However, north of Cape Cod leatherbacks are the more abundant species (Shoop and Kenney 1992), while around Puerto Rico and the Virgin Islands loggerheads are much less abundant than greens, hawksbills, and leatherbacks (Hillis-Starr et al. 1998).

Off the northeast U.S., loggerheads are commonly sighted from the shore to the shelf break as far north as Long Island, although further north and east, sightings are sparse (CETAP 1982; Shoop and Kenney 1992). Loggerheads are generally restricted to mid-Atlantic waters below 38°N, with mean surface temperatures of 22.2°C (Shoop and Kenney 1992). North of Cape Hatteras, loggerhead sea turtle occurrence is highly seasonal, primarily from May to October with a peak in June, though sightings have occurred in all months of the year (CETAP 1982; Lutcavage and Musick 1985; Shoop and Kenney 1992). South of Cape Hatteras, loggerhead sea turtles are year-round residents. During winter, most loggerheads are concentrated in waters of the southeast U.S. between 20 and 40 m deep (Schroeder and Thompson 1987). In warmer months (June through September), loggerheads tend to stay within 2 to 3 km of the shore, although individuals are sometimes found far offshore (Lee and Palmer 1981). Two loggerheads that were satellite-tracked off North Carolina were later found to have entered and traveled in the Gulf Stream (Keinath et al. 1996).

Loggerhead sea turtles nest almost exclusively in warm-temperate regions. Migrations from foraging grounds to nesting beaches may range from a few to thousands of kilometers (Meylan 1995). Females typically nest on continental coastlines adjacent to warm-temperate currents (Dodd 1988). In the western North Atlantic Ocean there are at least four demographically independent loggerhead nesting groups or subpopulations: (1) Northern: North Carolina, South Carolina, Georgia, and northeast Florida (approximately 7,500 nests in 1998); (2) South Florida: occurring from 29°N on the east coast to Sarasota on the west coast (approximately 83,400 nests in 1998); (3) Florida Panhandle: Eglin Air Force Base and the beaches near Panama City, FL (approximately 1,200 nests in 1998); and (4) Yucatán: the eastern shore of the Yucatán Peninsula, Mexico (approximately 1,000 nests in 1998) (Encalada et al. 1998; TEWG 2000). Small but significant nesting aggregations are also known from the Dry Tortugas, the Bahamas, and Cuba (Dodd 1988; Eckert et al. 1992).

Genetic evidence has shown that groups of benthic-feeding immature loggerheads on foraging grounds comprise a mix of subpopulations (Sears et al. 1995; TEWG 1998; Epperly et al. 2001). At least two of the subpopulations intermingle on the foraging grounds of the U.S. Atlantic coast. Norrgard (1995) found that turtles hatched from the northern subpopulation rookeries selectively use more northerly summer developmental habitats (such as Chesapeake Bay) than loggerheads from Florida rookeries. Epperly et al. (2001) reported that the northern subpopulation accounts for 46% of the loggerheads observed in Virginia. The south Florida subpopulation composes 65 to 66% of the loggerheads off the Carolinas and declines to 46% north of Cape Hatteras (Epperly et al. 2001). Genetic data collected from loggerheads in the Albemarle-Pamlico Estuarine Complex revealed that loggerheads from the south Florida subpopulation were most abundant there (Epperly et al. 2001).

- Information Specific to PROA/St. Croix OPAREA—As demonstrated by the small number of sightings, strandings, and incidental bycatches, the occurrence of loggerhead sea turtles in the PROA/St. Croix OPAREA is low/unknown during all seasons (Figure C-5). Loggerhead encounters in the waters surrounding Puerto Rico and the Virgin Islands are infrequent and almost always involve individuals that are in transit to more temperate foraging or nesting areas (Hillis-Starr et al. 1998). Nesting in this region is rare, as indicated by the lack of nesting data for both Vieques and the British Virgin Islands (Rainey 1979; Eckert et al. 1992; DoN 1996). However, since both the Caribbean Sea Current and the Antilles Current sweep past the waters of the PROA/St. Croix OPAREA (see Figure 4-1), it is probable that small numbers of juvenile loggerheads may be present in the waters surrounding Puerto Rico and the Virgin Islands at any time. Entrained loggerheads may travel with these currents on their way from the early juvenile developmental habitat off Europe to the late juvenile developmental habitat off the eastern U.S., Cuba, and Mexico (Eckert and Abreu-Grobois 2001).

Behavior and Life History—The diet of a loggerhead sea turtle changes with age and size of the turtle. The gut contents of post-hatchlings found in masses of *Sargassum* contained parts of *Sargassum,* zooplankton, jellyfish, larval shrimp and crabs, and gastropods (Carr and Meylan 1980; Richardson and McGillivary 1991; Witherington 1994b). Juvenile and subadult loggerhead sea turtles are omnivorous, foraging on pelagic crabs, mollusks, jellyfish, and vegetation captured at or near the surface (Dodd 1988). Adult loggerheads are generalized carnivores that forage on nearshore benthic invertebrates (Dodd 1988).

Estimates of the age at sexual maturity for western Atlantic loggerheads range from 12 to 30 years (Zug et al. 1986; Klinger and Musick 1992). Females typically nest three to five times per season, at about two-week intervals (Dodd 1988; Frazer 1998). Loggerhead clutches contain between 95 and 150 eggs and often take 60 days to incubate. The most common inter-nesting interval is two years (Dodd 1988; Frazer 1998). Most nesting in the U.S. occurs between April and September (NMFS and USFWS 1991b).

On average, loggerhead sea turtles spend over 90% of their time underwater (Byles 1988; Renaud and Carpenter 1994). Routine dive depths of 9 to 22 m have been recorded (e.g., Byles 1988; Sakamoto et al. 1990). Dives of up to 233 m were recorded for a post-nesting female loggerhead (Sakamoto et al. 1990). Routine dives typically can last from 4 to 172 min (Byles 1988; Sakamoto et al. 1990; Renaud and Carpenter 1994).

- Kemp's Ridley Sea Turtle (*Lepidochelys kempii*)

Description—The Kemp's ridley is the smallest living sea turtle. The straight carapace length is around 65 cm; adult Kemp's ridley shells are almost as wide as they are long (USFWS and NMFS 1992). The carapace is round to somewhat heart-shaped and distinctly light gray.

Status—Kemp's ridley sea turtles are classified as endangered under the ESA (USFWS and NMFS 1992); they are considered the most imperiled of the world's sea turtles. The worldwide Kemp's ridley population declined in numbers from tens of thousands of nesting females in the late 1940s to approximately 300 nesting females in 1985 (TEWG 2000). From 1985 to 1999, the number of nests at

Rancho Nuevo, Tamaulipas Mexico (the most important Kemp's ridley nesting beach) and nearby beaches has increased at a mean rate of 11.3% per year (TEWG 2000). Current totals at these beaches exceed 3,000 nests per year (TEWG 2000). There are no estimates of the total abundance of the population (Weber 1995).

Habitat Preferences—Kemp's ridley sea turtles occur in open-ocean habitats as post-hatchlings and young juveniles, and then move to benthic, inshore and nearshore feeding grounds in warm waters as older juveniles and adults.

Scientists have developed a habitat suitability index (HSI) model for the Kemp's ridley based on what is known of its habitat preferences. In addition to water temperature, habitat factors of critical importance to this species include water depth and prey abundance. Using what is known about the affinity of the Kemp's ridley for shallow coastal waters and their aversion to cold temperatures, scientists have made estimates regarding the suitability of various parts of the northwestern Atlantic Ocean and Gulf of Mexico for the species (Coyne et al. 1998). In this theoretical, quantitative model, the most optimal habitats for Kemp's ridleys are those with a bottom depth of less than 10 m and a sea surface temperature between 22° and 32°C. A cycling of HSI model outputs by month for the Atlantic and Gulf coasts can be viewed at http://www.seaturtle.org/research/hsi.html. Habitat suitability indices have not been devised for the Caribbean, as this species likely does not venture into this region.

Distribution—Kemp's ridley sea turtles are restricted to the North Atlantic Ocean (Márquez-M. 1994). They occur primarily in the Gulf of Mexico but occur in moderate numbers along the northeast U.S. coast as far north as Nova Scotia (Lazell 1980; Morreale et al. 1992). Juveniles and subadults are the main age-classes found in the northern part of their range. Kemp's ridleys are reported eastward as far as the British Isles, Netherlands, France, and the Azores (Brongersma 1995).

Nesting occurs primarily at Rancho Nuevo in Tamaulipas, Mexico (USFWS and NMFS 1992) with a few additional nests in Texas, Florida, South Carolina, and North Carolina (Meylan et al. 1990; Weber 1995; Foote and Mueller 2002). Kemp's ridleys that nest in south Texas today are likely a mixture of returnees from the experimental imprint/head-start project and others from the wild stock (Shaver and Caillouet 1998).

Oceanic transport of neonate Kemp's ridleys is primarily controlled by patterns of circulation in the Gulf of Mexico (Collard 1990b). Some juveniles are probably retained in the northern Gulf of Mexico, until they migrate inshore and become demersal. Others may be swept out of the Gulf of Mexico by the Loop and Florida Currents and then carried north along the U.S. Atlantic coast by the Gulf Stream (Collard and Ogren 1990). These currents transport juvenile sea turtles until they reach a size of approximately 20 to 30 cm, at which point they actively migrate to neritic developmental habitats (TEWG 1998). Along the Atlantic coast, known feeding areas include Cape Cod Bay, Long Island Sound, Chesapeake Bay, and the bays and sounds from North Carolina south (Lazell 1980; Lee and Palmer 1981; Lutcavage and Musick 1985; Barnard et al. 1989; Weber 1995). In the Gulf of Mexico, feeding areas occur along the entire coastline of the U.S. and Mexico (Renaud 1995).

Adults appear to remain in the Gulf of Mexico, with an occasional occurrence in the Atlantic Ocean. Satellite-tracked adult females moved very little and maintained relatively small ranges, while nothing is known of the ranging patterns of adult males (Weber 1995).

- Information Specific to PROA/St. Croix OPAREA—There are no records of Kemp's ridley sea turtles in the vicinity of the PROA/St. Croix OPAREA; therefore, an occurrence map for this species is not provided. Up until 1990, there were no records of Kemp's ridley occurrences in the entire Caribbean region (Ross et al. 1989). The only confirmed sighting of this species in the Caribbean occurred during an incidental capture near Miskito Cay, Nicaragua (Manzella et al. 1991). Since Nicaragua is a great distance away from Puerto Rico and the Virgin Islands, it is highly unlikely that a Kemp's ridley will ever be encountered in the PROA/St. Croix OPAREA.

Behavior and Life History—Kemp's ridley sea turtles feed primarily on portunids and other crabs but also are known to eat mollusks, shrimp, fish, and plant material (Ernst et al. 1994; Márquez-M. 1994). This species may possibly feed on shrimp fishery bycatch (Landry and Costa 1999).

The Kemp's ridley is a daytime nester with mass nesting taking place on windy days (Márquez-M. 1990). Females are estimated to become sexually mature at ages of 11 to 12 years. Females nest approximately every two years, usually doing so between April and mid-August. A typical female produces about three clutches averaging 110 eggs at 20- to 28-day intervals (Miller 1997). Incubation time from deposition to emergence is 48 to 65 days.

Few data are available on the maximum duration of dives. Satellite-tagged juvenile Kemp's ridley sea turtles show different mean surface intervals and dive depths depending on whether they are located in shallow coastal areas (short surface intervals) or in deeper, offshore areas (longer surface intervals). Dive times have been documented to range from a few seconds to a maximum of 167 min with routine dives lasting between 16.7 and 33.7 min (Mendonca and Pritchard 1986; Renaud 1995). Over a 12-hour period Kemp's ridleys will spend between 89% and 96% of that time submerged (Byles 1989; Gitschlag 1996).

- Olive Ridley Sea Turtle (*Lepidochelys olivacea*)

Description—The olive ridley is a small, hard-shelled sea turtle named for its olive green colored shell. Adults often measure between 60 and 70 cm in carapace length (NMFS and USFWS 1998). The olive ridley differs from the Kemp's ridley in that it possesses a smaller head, a narrower carapace, and several more lateral carapace scutes than its relative.

Status—Olive ridleys are classified as threatened under the ESA, although the Mexican Pacific coast population is labeled as endangered. Since listing, there has been a general decline in the abundance of this species (NMFS and USFWS 1998). For example, nesting populations in the western North Atlantic have declined more than 80% since 1967 (Reichart 1993). However, in terms of absolute numbers, the olive ridley is considered the most abundant of the world's sea turtles, although there are no current estimates of worldwide abundance.

Habitat Preferences—Olive ridley sea turtles typically inhabit offshore waters, foraging either at the surface or at depth (up to 150 m). Strangely enough, the habitat preferences of the olive ridley more closely parallel those of the leatherback sea turtle rather than those of its relative, the Kemp's ridley (NMFS and USFWS 1998). Olive ridleys and leatherbacks both occupy oceanic habitats and both nest primarily on the Pacific shores of the American tropics and in the Guianas. Both species also nest in moderate numbers in tropical West Africa and southern Asia, and in relatively small numbers elsewhere (both rarely nest in Australia and on other smaller oceanic islands in the Pacific Ocean).

Distribution—The olive ridley sea turtle is a pantropical species, occurring worldwide in tropical and warm temperate waters. In the Atlantic Ocean, the olive ridley occurs along the coasts of both Africa and South America, but probably not in great abundance. Atlantic olive ridleys nest primarily in the Guianas and Surinam; however, they are rarely found in the Caribbean Sea north of Trinidad. In the Pacific Ocean the range of the olive ridley is much more extensive, with individuals regularly occurring in waters as far north as California and as far south as Ecuador (NMFS and USFWS 1998).

- Information Specific to PROA/St. Croix OPAREA—As indicated by the lack of occurrence records, minus the lone incidental bycatch off the west coast of Puerto Rico, olive ridley sea turtles are not expected to occur in the PROA/St. Croix OPAREA and vicinity during any season (Figure C-6). Caldwell and Erdman (1969) noted that olive ridleys are very rare in Puerto Rican waters, since the Greater Antilles are located beyond the northern portion of the species' Atlantic range. Extralimital sightings, strandings, and bycatch have been documented, though, in Cuba, Puerto Rico, and islands in the eastern Caribbean (Caldwell and Erdman 1969; Márquez-M. 1990; Horta et al. 2000; Moncada et al. 2000). However, events such as these are extremely

uncommon and are always a result of individuals wandering or drifting (if dead) beyond their normal range (Reichart 1993; Moncada et al. 2000).

Behavior and Life History—The olive ridley sea turtle eats a variety of benthic and pelagic prey items, with crustaceans and fish serving as their main food source (NMFS and USFWS 1998).

Like the Kemp's ridley, the olive ridley is also known for nesting en masse. However, in the western Atlantic Ocean, it has been over 20 years since this activity was last observed (Eckert and Abreu-Grobois 2001). There is currently no estimate of the age at which females begin to reproduce; however, the average length of nesting olive ridleys at Playa Nancite, Costa Rica was 63.3 cm. Nesting occurs throughout the year, although it peaks from September to December in the Pacific Ocean. Females usually nest every one to two years. A typical female produces two clutches per nesting season averaging 105 eggs at 15- to 17-day intervals for lone nesters and 28-day intervals for mass nesters (NMFS and USFWS 1998). Incubation time from deposition to emergence is approximately 55 days.

3.2.3 Literature Cited

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4.0 HABITATS OF CONCERN

4.1 MACROALGAE—*SARGASSUM*

Sargassum natans and *S. fluitans* are pelagic brown algae that grow as clumps and mats of floating marine vegetation. *Sargassum* forms an integral habitat for a varied array of marine flora and fauna (Settle 1993). Nearly 90% of the pelagic *Sargassum* circulating in the North Atlantic is comprised of the species *S. natans* (SAFMC 1998a). The remaining 10% is made up of *S. fluitans* and a small amount of sessile/benthic *Sargassum* loosened from the seafloor (Dooley 1972). Individual plants of both pelagic species typically grow 20 to 80 cm in length and have a highly branched thallus (stem) with numerous leafy blades and berry-like pneumatocysts (air bladders) (SAFMC 1998a). Pelagic *Sargassum* is entirely holopelagic, propagating and growing exclusively at the sea surface throughout its life span (Butler et al. 1983). Sessile/benthic *Sargassum* is attached to bottom substrates by means of a holdfast (Kaplan 1988; Humann 1998). Sexual reproduction is not known to occur in either pelagic species. *Sargassum* appears to propagate asexually by fragmentation and continual growth (Coston-Clements et al. 1991). In the Caribbean Sea, *Sargassum* mats attract opportunistic foragers such as the dolphinfish, which feed on *Sargassum*-associated fishes such as the *Sargassum* triggerfish (Oxenford and Hunte 1999). Large oceanic pelagic fishes that feed around *Sargassum* aggregations are important to commercial, artisanal, and recreational fisheries in the Caribbean Sea. *Sargassum* aggregations in the Caribbean Sea also host larval fishes that are transported from the Caribbean region and that take up residence in North American waters and estuaries (Frias-Torres and Gilmore 1999).

4.1.1 Pelagic Movements of Sargassum

Sargassum movement and aggregation in the ocean is often determined by local surface circulation. It frequently aggregates into mats or meandering rows, called windrows or weed lines formed by wind-generated, helical, vertical eddies known as Langmuir circulation cells. Linear aggregations also form along thermal fronts where the intersection of warm and cool water masses create frontal boundaries (Coston-Clements et al. 1991). Small frontal eddies that veer off the major currents of the North Atlantic Gyre also aggregate *Sargassum* at the surface (Butler et al. 1983). Predicting the occurrence and activity of any of these three of these aggregating mechanisms is similar to predicting weather patterns and is limited in scope and accuracy. Human-made debris is often found floating in *Sargassum* weed lines.

In addition to the lateral movements of pelagic *Sargassum* at the sea surface, an unknown quantity of *Sargassum* travels downward from the surface to the seafloor. This can occur after the death of a clump of large plants, when large epiphytes make the *Sargassum* clump negatively buoyant, or when transported by downwelling currents. *Sargassum* can thus be a source of nutrients for bottom-dwelling organisms (Schoener and Rowe 1970).

4.1.2 Sargassum Habitat

Pelagic *Sargassum* contributes very little primary productivity to the upper water column of the Sargasso Sea or Caribbean Sea, but it does, however, play an important role as a habitat for other marine organisms. In particular, floating *Sargassum* serves as a temporary habitat for sea turtle hatchlings, and larval and juvenile stages of over 100 fish species (SAFMC 1998a). The habitat created by *Sargassum* aggregations also supports a diverse and highly adapted resident assemblage of marine organisms such as fungi, micro- and macro-epiphytes, hydroids, crustaceans, and fishes. Four species of sea turtles and numerous marine birds use pelagic *Sargassum* habitat as well (SAFMC 1998a). Sea turtle hatchlings are known to associate with pelagic *Sargassum* habitat during their “lost years” when they drift along with the floating mats. This association is thought to play a vital role in the life of young turtles (Carr 1987). Fronts and eddies of major currents located near the turtles’ nesting beaches are likely places where both hatchling sea turtles and *Sargassum* will occur. Unfortunately, there is currently a lack of information describing the association of sea turtles with pelagic *Sargassum* in the vicinity of the PROA/St. Croix OPAREA. However, any pelagic *Sargassum* mats drifting at sea have the potential for hosting young sea turtles since both are found with currents, and can travel for long distances from their points of origin

(Carr 1987). *Sargassum* aggregations located downstream of nesting beaches would generally be more likely to have hatchlings than those mats drifting in from the northeastern portions of the North Atlantic.

Juvenile fishes are by far the dominant vertebrate inhabitants of pelagic *Sargassum* habitats, yet adults of many large pelagic fish species are also commonly found swimming under and around *Sargassum* weed lines. These fishes are thought to be attracted to the drifting algal mats for a number of reasons, including its use as a foraging area, for protection from larger predators, and as a spawning ground (SAFMC 1998a). Fish population studies have indicated that temporal and geographic factors affect the composition and abundance of the fish species found associating with the algal mats (Settle 1993; SAFMC 1998a). In addition, the occurrence of associated fishes is affected by mat morphology and age (SAFMC 1998a). The size and shape of mats were found to significantly affect the relative diversity of *Sargassum*-associated fishes, with more fish species seen under larger mats than small clumps (Moser et al. 1998).

4.1.3 Status of Sargassum

Currently, the status of *Sargassum* in the North Atlantic, Caribbean, and Gulf of Mexico is uncertain. While the exact total biomass of pelagic *Sargassum* is unknown, estimates of standing crop in the Sargasso Sea range from about 4 to 11 million tons (Butler et al. 1983). Stoner (1983) sampled *Sargassum* in the North Atlantic, Caribbean, and Gulf of Mexico from 1977 to 1981, and found that the overall biomass of pelagic *Sargassum* declined by 6%. Ocean pollutants such as hydrocarbons and other man-made toxins are possible sources of the decline in *Sargassum* biomass (Stoner 1983).

Pelagic *Sargassum* plays a unique role in the open ocean surface environment. Consequently, the South Atlantic Fishery Management Council (SAFMC) has developed habitat and fishery management plans (FMP) (SAFMC 1998a, 1998b). The Caribbean Fishery Management Council (CFMC) currently has no rules or regulations concerning interaction with or the use of pelagic *Sargassum.* The lack of information concerning the biological associations of *Sargassum* communities in the Caribbean region and the limited amount of data on pelagic *Sargassum* occurrence in the Caribbean has prevented any steps toward protecting the habitat.

No regular or organized harvesting of pelagic *Sargassum* currently takes place in the Caribbean Sea or in the vicinity of the PROA/St. Croix OPAREA. However, fishermen, either commercial or recreational, may target *Sargassum* weed lines for pelagic fishes associated with floating ocean debris, such as dolphinfish and wahoo (García-Moliner personal communication). Targeting the occasional occurrence of *Sargassum* weed lines is more of an opportunistic than a regular fishing method.

4.1.4 Distribution of Sargassum

Pelagic *Sargassum* is found in most tropical and temperate oceans and in the Red Sea. In the North Atlantic, pelagic *Sargassum* occurs mainly within the physical bounds of the North Atlantic Gyre between 20° and 40°N and between 30°W and the western edge of the Gulf Stream, a region known as the Sargasso Sea (Figure 4-1). The greatest concentration in the Sargasso Sea occurs between 28°N and 34°N. This area, south of the Island of Bermuda, seems to be the center of *Sargassum* distribution in the North Atlantic (Dooley 1972; SAFMC 1998a). Some exchange occurs between the *Sargassum* populations of the Caribbean Sea, the Gulf of Mexico, and the North Atlantic. Westward-flowing currents of the southern North Atlantic Gyre carry considerable amounts of *Sargassum* to the Leeward Islands of the Antilles, the straits between the Bahaman Bank and Cuba, and on to the Florida Straits where the Florida Current joins the Gulf Stream (Dooley 1972). In contrast, very little *Sargassum* is found in the central Caribbean Sea (Dooley 1972).

4.1.4.1 *Sargassum* of the PROA/St Croix OPAREA

Pelagic *Sargassum* appears in portions of the PROA/St. Croix OPAREA and around the islands of Puerto Rico and the U.S. Virgin Islands (USVI). The occurrence of pelagic *Sargassum* is dependent on the

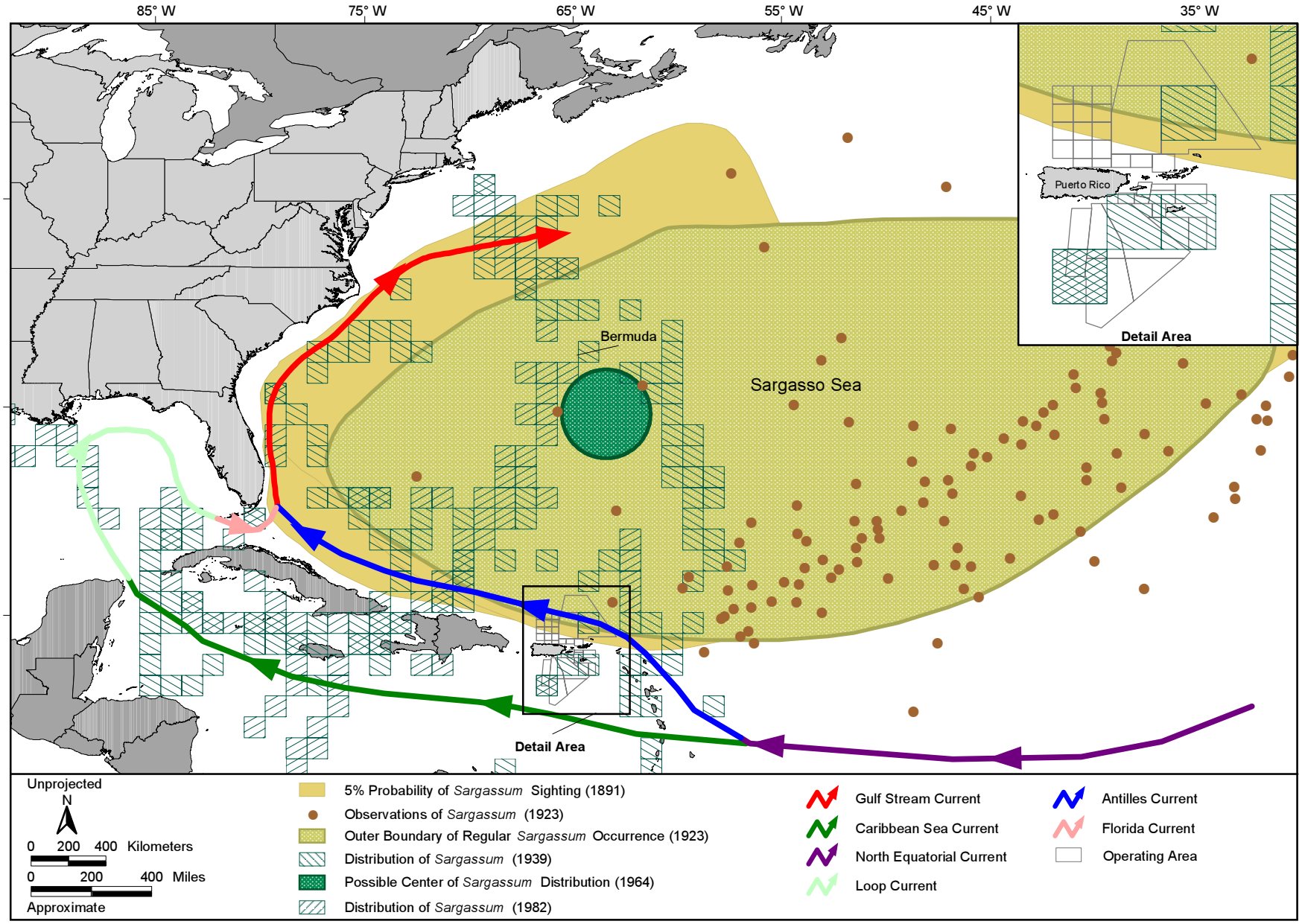

Figure 4-1. Historical distribution of pelagic *Sargassum* in the Caribbean Sea, Gulf of Mexico, and North Atlantic Ocean as well as the major surface currents that affect the distribution. Source maps (scanned): Dooley (1972), Pickard and Emery (1982), Butler et al. (1983), and General Oceanics (1986).

action of currents and fronts in the North Atlantic and Caribbean Sea (García-Moliner personal communication). Drifting *Sargassum* in the PROA/St. Croix OPAREA probably originates in the Sargasso Sea and is transported to the Caribbean by surface currents (Figure 4-1). Although no specific information exists regarding the amount or distribution of pelagic *Sargassum* in the Caribbean Sea, *Sargassum* is most likely found in the vicinity of the leeward island shelves and in the northern portion of the OPAREA, between the Leeward Islands and Bermuda.

4.2 LIVE/HARD BOTTOM COMMUNITIES, CORALS, AND CORAL REEFS

4.2.1 Hard Bottom Communities: Uncolonized Hard Bottom

Unlike the continental shelf of North America, the PROA/St. Croix OPAREA does not contain live/hard bottom communities in a strict sense. Live/hard bottom communities found off the U.S. Atlantic coast are small, isolated areas of low, rough, or broken relief consisting of naturally occurring hard or rocky outcrops sometimes colonized by rich biological assemblages (sea fans, sea whips, ascidians, bryozoans, hard/soft corals, hydroids, anemones, and sponges). These live/hard bottom areas are the locations of dense aggregations of turtles, commercial/recreational fishes, and other fauna (Cahoon et al. 1990; Thompson et al. 1999). In the PROA/St. Croix OPAREA, the hard bottom substrate is not colonized with sessile organisms and does not stand out as a unique or significant biological community unlike the coral reefs and seagrass beds or meadows.

Four of the twenty-six benthic habitat types the National Ocean Service (NOS) (2001) identified for Puerto Rico and the U.S. Virgin Islands (USVI) are uncolonized hard bottom: reef rubble, uncolonized pavement, uncolonized bedrock, and uncolonized pavement with sand channels.

- Reef rubble: dead, unstable coral rubble often colonized with filamentous or other macroalgae. This habitat often occurs landward of well-developed reef formations in the reef crest or back reef zone.

- Uncolonized pavement: flat, low relief, solid carbonate rock that is often covered by a thin sand veneer. The pavement's surface often has sparse coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that does not obscure the underlying carbonate rock.

- Uncolonized bedrock: exposed bedrock contiguous with the shoreline that has sparse coverage of macroalgae, hard coral, gorgonians and other sessile invertebrates that does not obscure the underlying rock.

- Uncolonized pavement with sand channels: habitat having alternating sand and uncolonized pavement formations that are oriented perpendicular to the shore or bank/shelf escarpment. The sand channels of this feature have low vertical relief compared to spur and groove formations. This habitat type occurs in areas exposed to moderate wave surge such as that found in the bank/shelf zone.

Areas containing uncolonized hard bottom in Puerto Rico and the USVI are few. On Puerto Rico, they are located at the center of the southern shore and the southwestern tip (Figure 4-2). Uncolonized hard bottom areas are also found at Desecheo (Figure 4-2) as well as in many small areas surrounding St. Thomas, St. John, and along the northern shore of St. Croix (Figure 4-3).

4.2.2 Coral and Coral Reefs

Coral reefs are tropical, mostly shallow ecosystems, largely restricted to the area between 30°N and 30°S (UNEP/IUCN 1988). Coral reefs as marine ecosystems in which “a prominent ecological functional role is played by scleractinian corals” (McManus 2001) or “normal” coral reefs as biogenic “production-dominated reefs” (Kleypas et al. 2001) occur abundantly in the general area bordering the PROA/St. Croix OPAREA. Such coral reefs occur in areas surrounding over 100 islands, cays, rocks, and keys surrounding Puerto Rico, the USVI, and the British Virgin Islands (BVI) (Figures 4-2 and 4-3). Inshore

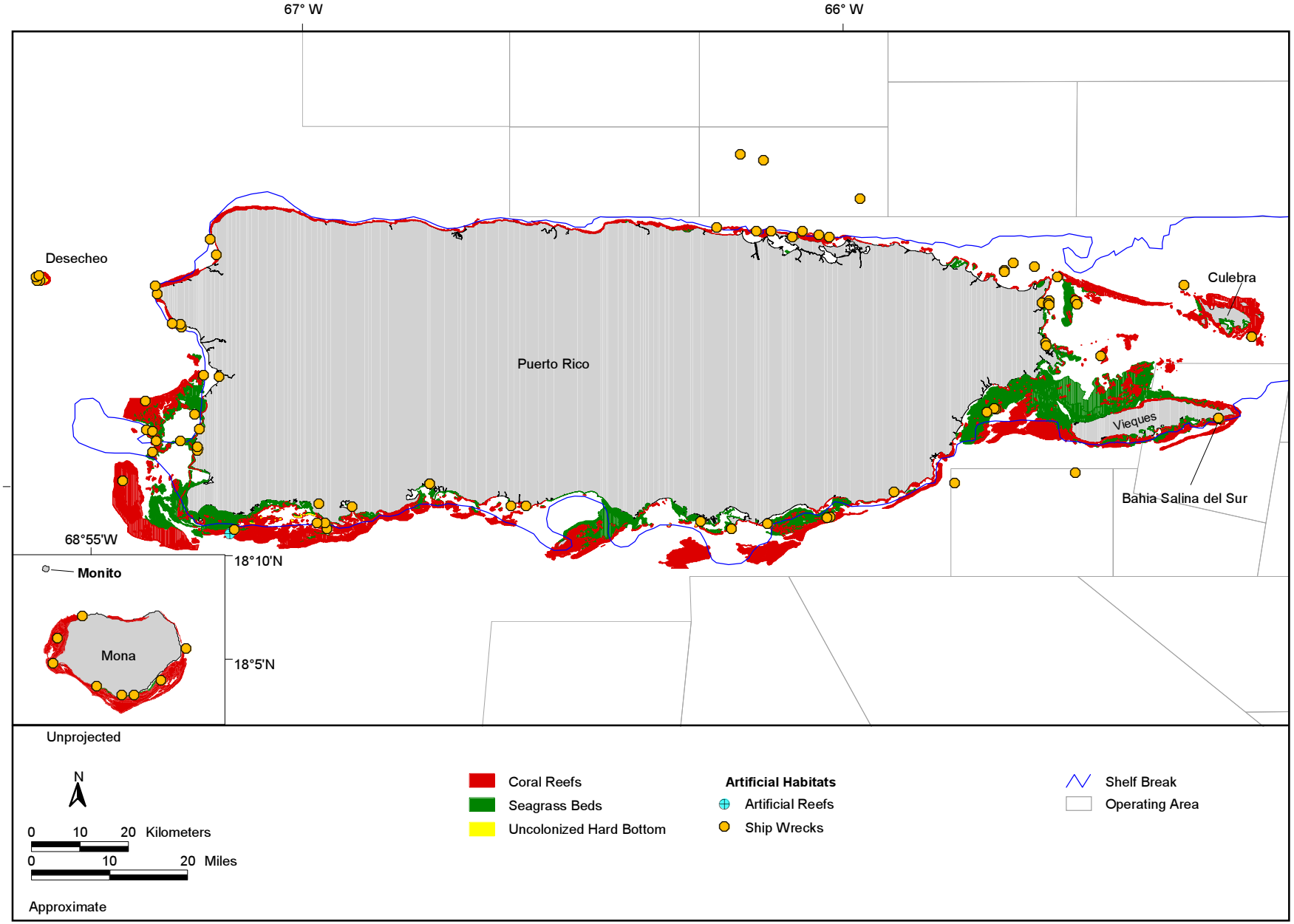

Figure 4-2. The distribution of coral reefs, hard bottom substrate, seagrass beds, and artificial habitats in the vicinity of Puerto Rico. Source data: Cerame Vivas (1988), Berg and Berg (1989), Waterproof Charts, Inc. (1998), Simonsen (2000), Handler (2001), and NOS (2001). Source map (scanned): Spalding et al. (2001).

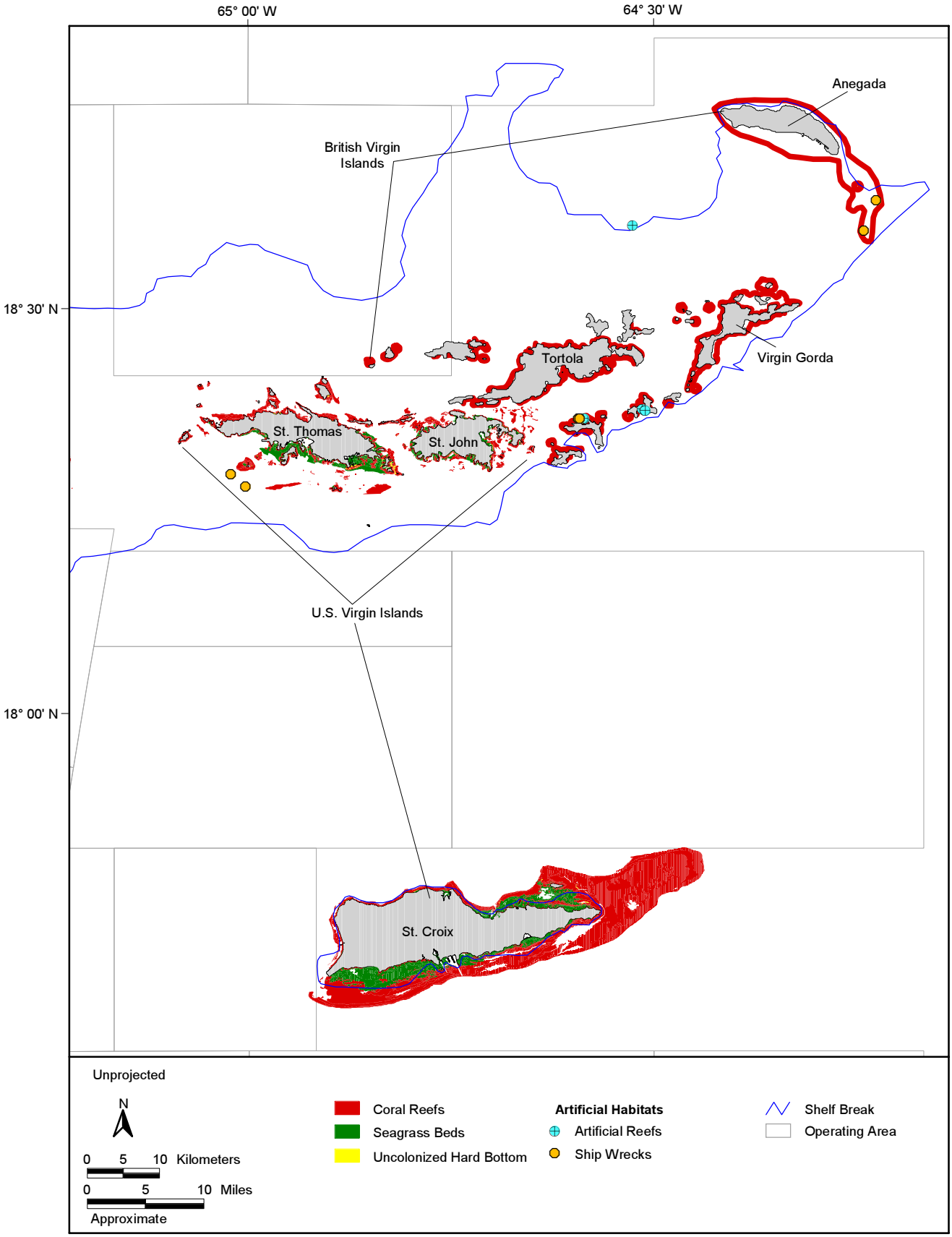

Figure 4-3. The distribution of coral reefs, hard bottom substrate, seagrass beds, and artificial habitats in the vicinity of the Virgin Islands. Source data: Berg and Berg (1989), Waterproof Charts, Inc. (1998), Simonsen (2000), Handler (2001), and NOS (2001). Source map (scanned): Spalding et al. (2001).

waters of Caribbean islands host some of the most diverse biota found in any of the U.S. Atlantic Ocean states or possessions (CFMC 1998). Coral reefs exist within the general PROA/St. Croix OPAREA because of favorable physical-environmental parameters (Veron 1995). Latitude-correlated physical-environmental parameters driving the growth of coral reefs in this area include optimal temperature, light, substrate, and currents. Light availability is the most ecologically significant latitude-correlated physical-environmental parameter. Optimal light levels support the coral-zooxanthellae symbiosis to promote coral growth and reef accretion (Barnes and Chalker 1990). From 1985 through 1995 the open ocean average sea surface temperature in this area ranged from 26° to 28.8°C (Samuels 2002). Excessive seawater temperatures (30° to 34°C) cause coral bleaching (disruption of coral-zooxanthellae symbiosis; expulsion of zooxanthellae) and in some cases coral mortality (Hoegh-Guldberg 1999).

Non-latitude correlated or regional physical-environmental factors influencing the development of coral reefs in this area include surface circulation, substrate availability, sedimentary regimes, tidal regimes, and nutrient availability (Veron 1995). The most limiting of all regional physical-environmental parameters to reef coral distribution is substrate availability. Sedimentary regimes, associations of substrate type, sedimentation, turbidity and light availability will impact coral diversity and distribution at a local, macroenvironmental (shelf), and biogeographic scale (entire coral province) (Veron 1995). A more detailed characterization of U.S. Caribbean reefs can be found in CFMC (1998).

4.2.2.1 Coral Reefs of the PROA/St. Croix OPAREA

Coral reefs in the PROA/St. Croix OPAREA and vicinity were developed on the shallow Puerto Rico Platform that surrounds Puerto Rico's insular shelf and extends eastward around the Virgin Islands. The coral reefs of St. Croix are separated from those of the Puerto Rico and Virgin Island archipelago by the 4,500 m deep Virgin Island Trough (Figures 4-2 and 4-3). Most of the islands in the PROA/St. Croix OPAREA have a volcanic origin. Only Mona, St. Croix, and Anegada are uplifted carbonate islands (raised limestone layers) (Dillon et al. 1988).

Coral reefs in the PROA/St. Croix OPAREA and vicinity are potentially exposed to the following sources of human-induced threats that compound natural changes on reefs (including hurricane impacts): overfishing, polluted runoff (including sewage, pesticides), coastal development, upland deforestation, anchoring, and destructive fishing techniques (Sullivan-Sealy and Bustamante 1999; Causey et al. 2000). These sources of impact can or already have led to the serious deterioration of coral reef habitat and structure in reefs of Puerto Rico and the Virgin Islands as a result of nutrification, sedimentation, and mechanical damages to corals (Sullivan-Sealy and Bustamante 1999; Causey et al. 2000). Upland deforestation and the resulting sedimentation on fringing reefs (closest to shore) are thought to be the most significant threat to coral reefs in this area (CFMC 1998).

The CFMC established a FMP to restrict the taking of coral reef resources within Puerto Rico and the USVI's EEZ. The Coral FMP prohibits the harvest, possession, or sale of stony corals, sea fans, gorgonians, and other species attached to live-rock as well as the use of chemicals, toxins, or explosives to harvest any species (CFMC 1998). More than 100 species of coral and over 60 species of algae, seagrasses, and invertebrates are protected by the Coral FMP (CFMC 1998). The nearshore reefs and hard bottom areas adjacent to Puerto Rico and the USVI are designated as habitat areas of particular concern (HAPC) because of their fishery value. Hind Bank, southwest of St. Thomas, is an HAPC that is intended to protect corals and their associated flora and fauna (CFMC 1998) (see Figure 6-3 for the location of Hind Bank).

- Coral Reefs of Puerto Rico

  Coral reefs (rock, fringing, patch, shelf, and submerged shelf-edge) of Puerto Rico are most abundant along the west, south, and east coasts of the main island and around the islands of Culebra, Vieques, Mona, and Monito (UNEP/IUCN 1988; ReefBase 2000, 2002; Morelock et al. 2001; Spalding et al. 2001) (Figure 4-2). Fringing reefs off the main island of Puerto Rico develop off the shoreline where little rainfall occurs and where vegetation stabilizes soils. Fringing reefs are typical along the northeast, east, and southern coasts of the main island (Morelock et al. 2000). Patch reefs are for the

most part fully submerged and are found on the open shelf as pinnacles. Submerged shelf reefs (reef type between barrier and patch reefs but larger than patch reefs) are found in waters deeper than 15 m and form parallel to the shoreline. Coral cover on Puerto Rican reefs ranges from 0% to 44% (1 to 25 m depth range) (Causey et al. 2000). The total coral reef area is estimated at 480 km^2 (Spalding et al. 2001). Accelerated urban, industrial, and agricultural coastal development as well as overfishing over the past 40 years has severely impacted coral reefs of Puerto Rico (Causey et al. 2000; Spalding et al. 2001).

Human-induced stressors that impact the north and south coastal environments of Puerto Rico include water quality changes (increased terrigenous sediment input and increased nutrient/sewage input), coastal habitat loss caused by development, uncontrolled recreational activities, and the decline in species abundance (from overfishing) (Hernández-Delgado and Sabat 1998; Sullivan-Sealey and Bustamante 1999; Causey et al. 2000; Morelock et al. 2001).

The main naturally induced impacts on coral reefs are caused by hurricanes, storm damage, silt-laden runoff following heavy rainfall/floods, the Caribbean-wide morality of the long-spined urchin in the 1980s, repeated coral bleaching events of the 1980s, and widespread coral diseases (Glynn et al. 1964; Raymond and Dodge 1980; Goenaga and Canals 1990; Lugo-Fernández et al. 1994; Bruckner and Bruckner 1997; Causey et al. 2000; Morelock et al. 2001).

The additive pressures of naturally occurring and anthropogenic stresses have led to the critical status of Puerto Rican coral reefs (100% at risk; Spalding et al. 2001) and recently led to the development of increased measures for coral reef protection in Puerto Rico (including revised laws, creation of reserves, and mapping) (Causey et al. 2000; Garcia et al. 2000; Spalding et al. 2001).

Coral reef development on the main island of Puerto Rico is limited by the narrow width of the Puerto Rico insular shelf (north coast = 0.3 to 3.2 km; south coast = 5 to 21 km; west coast = 0.4 to 6.6 km), which is immediately bordered by deep water. Yoshioka and Yoshioka (1989) found 5% hard coral cover on the north coast (mostly rock reefs or platforms encrusted by corals) and algal beds occupying most of the hard bottom substrates. The lack of coral reef development on the northern coast (240 km coastline) is probably caused by a combination of environmental factors, including heavy wave action (particularly during winter) (Yoshioka and Yoshioka 1989; CFMC 1998; Morelock et al. 2000); heavy rainfall; heavy silt/clay-laden runoff from several major river deltas and estuaries (Sullivan-Sealey and Bustamante 1999; Morelock et al. 2000); longshore currents (UNEP/IUCN 1988); and possibly the lack of space on the narrow insular shelf. A fairly large but stressed reef exists off Dorado, located in the middle of the main island north coast (CFMC 1998). Other stressed reefs of the north coast include those east of San Juan. The northeast coast has more coral growth than the north because it is located upstream from freshwater runoff and has a broad shelf. The northeast coast also is somewhat protected from wave action by the emerging reefs that link the main island to Culebra. Hernández-Delgado and Sabat (1998) found fringing and shelf-edge reefs off the northeast coast. The condition of these reefs improved with distance from shore (Hernández-Delgado and Sabat 1998). The best reef development off the northeast coast was found around La Cordillera Islets and the islets of Isla Ramos, Isleta Marina, and Cayo Ahogado (CFMC 1998).

In comparison with other coasts of the main island, the southern coast of Puerto Rico (348 km coastline) has abundant coral reefs, including fringing and offshore reefs. Yoshioka and Yoshioka (1989) found coral cover on the southern side to range from less than 5% to more than 20%. Offshore reefs on the broader southern insular shelf are more developed than nearshore reefs because they are distanced from any river runoff and nearshore siltation and the dynamic water transport caused by the trade winds (Yoshioka and Yoshioka 1989; Sullivan-Sealey and Bustamante 1999; Morelock et al. 2001). West coast reefs are more protected from the wind and wave action that impact the south and north coasts (Morelock et al. 2001). The healthiest reefs of the Puerto Rico main island are probably those found off La Parguera on the southwest corner of island (Garcia et al. 1998; Firman et al. 1999; Morelock et al. 2001). On the west coast, Yoshioka and Yoshioka (1989) found that coral cover exceeded 10%. Morelock et al. (2001) found that over the past 20 years, coral cover on the south and west coasts of Puerto Rico ranged from 1% to in excess of 50%.

Coral reefs at Culebra Island occur as fringing, patch, and barrier reefs (Garrison et al. 2000). These coral reefs have been severely degraded by hurricanes and coral diseases as well as explosives (Rogers et al. 1978), anchoring, ship groundings, runoff (containing terrigenous sediments and sewage), and overfishing (Garrison et al. 2000). Hard coral cover at three monitoring sites at Culebra Island ranged from 9% to 31% (Garrison et al. 2000).

Coral reefs occur at Vieques Island as fringing, patch, and barrier reefs (Dodge 1981). The most studied coral reef locations at Vieques Island are shallow bays (water depth <10 m) of the eastern end of the island contained within the Navy's Inner Range (Rogers et al. 1978; Dodge 1981; Antonius and Weiner 1982; Macintyre et al. 1983). Up until 1983, elkhorn coral (*Acropora palmata*) was the dominant coral of the shallow (water depth <4 m), southeastern end of Vieques Island (Macintyre et al. 1983). Coral in shallow bays occurred mainly on hard promontories. Sand and rubble sediments characterize this shallow, sometimes high-energy environment colonized by *Thalassia* seagrass (Rogers et al. 1978; Macintyre et al. 1983).

The overall condition of coral reefs at the eastern end of Vieques Island is probably largely influenced by natural disturbances (Hurricane David in 1979, Hurricane Hugo in 1989, recurrent tropical storms, the 1983 mass mortality of the long-spined urchin, coral diseases, and mass coral bleaching). Unlike the coral reefs of the main island of Puerto Rico, Vieques Island coral reefs in the Navy Inner Range area are not impacted by water quality changes, coastal habitat loss caused by development/uncontrolled recreational activities, or the decline in species abundance (from overfishing) (Hernández-Delgado and Sabat 1998; Sullivan-Sealey and Bustamante 1999; Causey et al. 2000; Morelock et al. 2001). Military-related activities and the pressure of local fishing are probably the two most significant sources of human impacts on the Inner Range coral reef ecosystems.

In 1978, some very shallow coral reefs at Bahía Salina del Sur in the Vieques Island Inner Range exhibited low diversity, low percentage of live cover, and few coral taxa primarily due to exposure of the reef at low tide and high ambient temperatures (Rogers et al. 1978). Increased sedimentation induced by Navy range activities and the presence of debris may have caused local stress or lasting damage on coral colonies (Rogers et al. 1978). The extent of damages caused by range activities as reported in 1982 appeared to be restricted to few coral reef areas of the eastern end of Vieques Island (Antonius and Weiner 1982).

Macintyre et al. (1983) found that from water depths of 4 to 8 m, Bahía Salina del Sur contained assemblages of boulder star coral, symmetrical brain coral, and massive starlet coral heads with scattered elkhorn coral. Most *Acropora* stands and thick finger coral of Bahía Salina del Sur had been severely damaged by storm waves during Hurricane David in 1979 (Raymond and Dodge 1980). Any remaining acroporids have probably been decimated by subsequent storms (Hurricane Hugo in 1989) and white band disease (Antonius and Weiner 1982; Gladfelter 1982), particularly during the 1980s and 1990s.

A preliminary habitat classification of the nearshore waters off the Vieques Island Inner Range conducted in 2001 included a succession of three dominant reef habitats from the shoreline to the 20 m isobath: fringing reefs (approximate depth: 6 to 12 m), hardground areas or crest reefs (approximate depth: 6 m), and offshore reefs or reef slope habitat (approximate depth: 20 m) (DoN 2001). The reef coverage is greatest east of the Vieques Island Inner Range boundary, and offshore reefs are the dominant coral reef type (DoN 2001). Fringing reefs are also important in terms of cover and occurrence along the entire Vieques Island Inner Range shoreline. The hardground communities occur for the most part on the southern side of the Vieques Island Inner Range.

- Coral Reefs of the U.S. Virgin Islands

Coral reefs (fringing reefs, wall and shelf-edge reefs, spur and groove formations, offshore bank and patch reefs) occur around St. Thomas, St. John, and St. Croix and about 90 small islands and cays. The total reef area is estimated at 200 km^2 (Spalding et al. 2001). Up to 57 hard coral species occur on the USVI reefs. St. Croix has the most extensive reefs (bank barrier reefs, algal ridges, fringing

and patch reefs) (UNEP/IUCN 1988). Significant reefs of St. Croix are found along the eastern half of the island (including reefs coastal reefs and those in Buck Island National Monument) and in Salt River Submarine Canyon on the north coast (5% to 24% live coral cover; CFMC 1998). There are no prominent reefs recorded along the western side of St. Croix (closest to PROA/St. Croix OPAREA grid block UTR 11). Scattered coral colonies do occur on nearshore hard bottoms such as those immediately north of the Frederiksted Pier on the west coast.

A combination of natural and human-induced disturbances has severely degraded USVI coral reefs and their associated fisheries over the past 20 years. Eight hurricanes (particularly Hurricane David in 1979 and Hurricane Hugo in 1989) and coral diseases have caused significant coral mortality (Causey et al. 2000). Coral diseases impact 2% to 5.6% of hard corals in the USVI. Hurricane damage and white band disease have decimated elkhorn coral populations at Buck Island, St. Croix (from 85% cover in 1976 to 5% in 1988), and St. John. Although there have been repeated episodes of coral bleaching (more than 50% of corals), corals generally appeared to regain their pigmentation.

Anchoring and ship grounding have caused severe damage to coral reefs at St. John. The repeated groundings of small vessels on shallow reefs weaken coral colonies and make them less resilient to storm/hurricane damage and the onslaught of diseases. Anchoring and the deployment of fish traps on coral reefs and the intense recreational activity at coral reefs have severely impacted coral reef habitat. Despite the fact that a significant proportion of the USVI coral reefs are currently designated as reserves, there is a need for increased enforcement and enhanced regulations to prevent human-induced damages to coral reefs, including commercial fishing within protected areas, and to allow the recovery of reefs.

- Coral Reefs of the British Virgin Islands

Reefs of the BVI occur as patch reefs on the many outcrops found on the Puerto Rico Platform (10 to 50 m water depth) and as fringing reefs along most of the over 40 islands, cays, and rocks of the BVI archipelago. Extending to the southeast of Anegada, Horseshoe Reef is a long barrier-type reef (UNEP/IUCN 1988; Smith et al. 2000; Spalding et al. 2001). Coral reef areas range from small patches to the very large Horseshoe Reef (77 km^2). Like coral reefs of Puerto Rico and the USVI, coral reefs of the BVI are 100% at risk (Spalding et al. 2001). The total reef area is estimated at 330 km^2 (Spalding et al. 2001). Recent hurricanes have destroyed up to 100% of the live coral cover in some places. Hurricane Donna in 1960 and Hurricane Frederic in 1979 impacted reefs north of Virgin Gorda and at Anegada (UNEP/IUCN 1988). More recently, Hurricanes Jose and Lenny in 1999 caused damage to reefs on the eastern periphery of the BVI (Smith et al. 2000). Some recovery is underway. Coral diseases (1980s), mass mortality of the long-spined urchin (1984) and mass coral bleaching (1998) have also greatly impacted coral reefs of the BVI. Further, coastal development (construction of marinas, breakwaters, clearing of land, building and road construction), siltation, untreated sewage, and the pressure of tourist numbers and legitimate recreational activities (anchoring, yachting, snorkeling, diving) mainly near Jost Van Dyke Island, Tortola, and Virgin Gorda are severely impacting reefs (Spalding et al. 2001). Commercial and recreational fishing are also significantly impacting reefs of the British Virgin Islands. Even though several coral reef areas of the BVI are designated as protected areas (including Horseshoe Reef, The Baths, Wreck of the RMS *Rhone*), few receive actual protection from human disturbances (Smith et al. 2000; Spalding et al. 2001).

The BVI coral reefs contained within OPAREA grid block 4 of the PROA/St. Croix OPAREA surround or are found close to Tobago Island, Little Tobago Island, Jost Van Dyke Island, Little Jost Van Dyke Island, Green Cay, and Anegada (UNEP/IUCN 1988). Each of these locations was once proposed as a protected area (UNEP/IUCN 1988). At Tobago Island, live coral cover was 10% to 40% in 1 to 20 m water depth (UNEP/IUCN 1988). The southwestern coast of Little Jost Van Dyke Island had fringing reefs (20% coral cover) (UNEP/IUCN 1988). On the southeastern end of Little Jost Van Dyke Island, live coral cover ranged from 10% to 40% (UNEP/IUCN 1988). Green Cay had reefs off the southern and southeastern shores with 15% to 35% live coral cover (UNEP/IUCN 1988). Fringing coral reefs surround Anegada Island (including the barrier reef to the north, Pelican Point to the east, Horseshoe

Reef, and The White Horse to the southeast). The base of Horseshoe Reef (10 m deep) had an average 50% coral cover (UNEP/IUCN 1988). Up to 31 coral species were found at Anegada Island (UNEP/IUCN 1988).

4.3 SEAGRASSES

Unlike macroalgae, seagrasses are flowering plants (vascular) that reproduce asexually and sexually. Depending on water transparency (turbidity), seagrasses can grow on sand or mud substrates in water approximately 15 m deep (CFMC 1998). Seagrasses complete their life cycle while being fully submerged. Three common seagrass species most often found in the Caribbean are shoal grass (*Halodule wrightii*), Caribbean turtle grass (*Thalassia testudinum*), and manatee grass (*Syringodium filfiforme*) (Kaplan 1988). Turtle grass (flattened green leaves) is probably the most abundant seagrass species in the PROA/St. Croix OPAREA (Vincente 1992).

Seagrass beds are among the most highly productive of all natural systems in the world (Wiley and Vilella 2000). Seagrasses generally grow in protected areas such as bays or coves with slow currents and moderate wave action and are often found near protective barrier reefs (Kaplan 1988). Seagrass beds in the Caribbean are frequently associated with coral reefs. In many cases seagrass beds and coral reefs can be highly interconnected. Seagrass beds will trap sediments preventing sediment re-suspension and transport onto the adjacent reefs. In turn, reefs protect seagrass beds by dissipating wave energy.

Seagrass beds provide nutrients, energy, and habitat for fish and numerous marine invertebrates (Kaplan 1988; Vincente 1992). *Thallasia* leaves are used as substrate by algae, crustaceans, and hydrozoans. *Thalassia* leaves are a primary source of food for fishes, manatees, sea turtles, sea urchins, and gastropods (CFMC 1998). Sea turtles and manatees use the seagrass material itself as a primary food source. Seagrasses are the important part of the diet of the endangered green sea turtle (juvenile and adult stages). The endangered West Indian manatee feeds on roots, rhizomes, and leaves of seagrasses (Wiley and Vilella 2000). Fishes (grunts, wrasses, parrotfish, and snappers) and conch use seagrass beds as nursery grounds during their larval and juvenile life stages (CFMC 1998). Both juvenile and adult fish use seagrass beds as foraging grounds, feeding on the epiphytic organisms attached to grass blades and on the crustaceans and worms living among the stalks or burrowed in the substrate. Several coral reef animals use seagrass beds as secondary feeding grounds. Some fish (e.g., grunts, snappers) move between seagrass beds and coral reefs, feeding in the seagrass and providing carbon for detritivores on the reef (CFMC 1998). Several fish and invertebrate species feed on the sediment itself, extracting the organic material trapped there and the small creatures living among the sediment particles. Predatory fish such as the great barracuda use seagrass habitats to hunt, finding prey over and at the edges of the beds (Kaplan 1988).

4.3.1 Seagrass Beds of the PROA/St. Croix OPAREA

Seagrasses occur throughout the nearshore areas surrounding Puerto Rico, the USVI, and the BVI (Figures 4-2 and 4-3). Data on the distribution of seagrasses are currently limited to Puerto Rico and the USVI, which is why seagrasses do not appear in the vicinity of the BVI in Figure 4-3. Information presented here on seagrasses concentrates on the grid blocks within or near PROA/St. Croix OPAREA: grid blocks 2A, 2B, 3A, 3B, W-428, and 8 for Puerto Rico; grid block 4 north of St. Thomas and St. John; and grid block UTR (11) west of the western end of St. Croix. The more detailed discussion on seagrasses for this area will be focused on Puerto Rico since detailed information was unavailable for other areas.

Around Puerto Rico, seagrasses occur along the southwest, southern, eastern, and northeastern coasts of the main island (Figure 4-2). Seagrass beds surround Vieques Island and also grow off the southern coast of Culebra Island. A large area of seagrass beds covers the seafloor between the southeast coast of Puerto Rico and Vieques. In the USVI, seagrasses are found on eastern and southern shores of St. Thomas and surround St. John. Seagrasses occur everywhere around St. Croix except for the western coast and western half of the north coast. The distribution of seagrasses in the BVI is not known. One could safely assume that seagrasses are concentrated along the southern and eastern BVI shores.

Essential fish habitat (EFH) has been identified and described as occurring in all seagrass beds within the EEZ of Puerto Rico and the USVI for various lifestages of 17 selected fish and invertebrate species (CFMC 1998).

4.3.1.1 Seagrasses of Puerto Rico

Seven species of seagrasses occur in Puerto Rico: Caribbean turtle grass, the sea vines (*Halophila decipiens*, *H. baillonis*, and star grass [*H. engelmannii*]), shoal grass, manatee grass, and widgeon grass (*Ruppia maritima*) (Vincente 1992). *H. baillonis* and star grass are only found in a few locations off the north and southeast shores. *H. decipiens* is probably the most common and abundant seagrass species in Puerto Rico (Vincente 1992). It tolerates low salinity and turbidity and is therefore apt to invade polluted environments. Shoal grass is also a very common species but is restricted to shallow environments. Widgeon grass is restricted to lagoons with no oceanic influence (Vincente 1992). Four species occur on the shelf surrounding the main island as well as Culebra and Vieques islands: turtle grass, manatee grass, *H. decipiens*, and shoal grass.

There is very little seagrass growth (<5%) along the north and west coasts of Puerto Rico because of wave action, the narrow insular shelf, and silt-laden river runoff (Vincente 1992). There are large areas of manatee and turtle grass beds along the southwest, south, and east coasts of Puerto Rico where there is a wide, shallow shelf; a coastline protected from heavy wave action; and reduced river runoff (Vincente 1992).

The island of Vieques is almost completely encircled by seagrass beds. The three dominant species of seagrasses, in the order of their relative abundance at Vieques, are Caribbean turtle grass, manatee grass, and shoal grass. *H. decipiens* is also present seasonally in certain areas of turbid water such as Bahía Tapón, eastern Ensenada Honda, and Puerto Ferro. The most extensive beds around the island are found on the northwest side near Mosquito Pier. Beds with varying densities are found along the southern and eastern coasts of the island (Reid and Kruer 1998). The seagrasses located at the eastern end of Vieques grow mainly in the protected bays and coves that define the southern and eastern shorelines. Of special note are some dense, deeper water seagrass beds found offshore Puerto Mosquito and Puerto Ferro in 23 m of water (Reid and Kruer 1998). The distribution pattern of seagrass habitats around the island differs overall; Reid and Kruer (1998) attributed the patchwork of habitat types found on the southern shores to the varied geophysical characteristics of the area, which contrasts with the continuous shorelines and seagrass meadows on the northwestern side of the island. Zieman (2001) found more continuous seagrass coverage in Bahía Icacos than seen prior to 1985. Further, to the east, at Bahía Salinas, Zieman (2001) found no evidence of seagrass decline over previous years. At Bahía Salina del Sur, the seagrass beds have shown continued expansion since 1985, with numerous small beds enlarging and combining. The seagrass location near the end of the Inner Range runway target at Bahía Salina del Sur is the only area that shows impacts from military training exercises (Zieman 2001).

4.3.2 Human Impacts on Seagrass Beds

The main sources of impact that threaten seagrasses and the seagrass habitat in the general area of the PROA/St. Croix OPAREA include: raw sewage; agricultural runoff; coastal construction that obstructs incident light to seagrasses; pipe placement (telephone, water, electricity); mechanical impacts (anchoring, scaring, ship grounding); silt-laden runoff (upland and coastal deforestation land clearing); overfishing and illegal hunting; sand burial and turbidity following storms and hurricanes; and disease (CFMC 1998; Sullivan-Sealy and Bustamante 1999). Threats to seagrasses in Puerto Rico are caused by environmental stress caused by poor water quality, the loss of species abundance, and the loss of habitat along northern and southern Puerto Rico (Sullivan-Sealy and Bustamante 1999).

The Region 4 Director of the USFWS has classified the seagrass beds of Culebra a Resource Category 1 Designation, indicating that these seagrass areas are considered unique and irreplaceable and the loss of this system would be unacceptable. Section 404 of the CWA and Section 10 of the River and Harbor Act protect Culebra's seagrass beds, since federal permits required by these laws are necessary for development in these areas (CFMC 1998).

4.4 ARTIFICIAL HABITATS

Artificial habitats (shipwrecks, artificial reefs, and other man-made structures) represent physical alterations to the seafloor. Under the right conditions, these types of artificial habitats can benefit benthic communities and onshore economies. The benefits experienced by marine biological communities increase with time. When solid hard objects with numerous and varied surfaces are introduced to areas of the seafloor predominantly composed of soft sediments, they provide the appropriate substrates necessary for the settlement and colonization of epibenthic organisms such as algae, sponges, barnacles, soft corals, anemones, and hydroids among others (Bohnsack et al. 1991). As more organisms assemble at an introduced site, an interrelated community develops, ultimately attracting larger predatory game fish that in turn bring recreational and commercial fishermen. The preservation of a successful artificial habitat can have a bearing on the biological productivity and economic value of offshore areas.

Although artificial in their origin and in their design, benthic artificial reefs and shipwrecks behave like natural hard bottom communities once established (Bohnsack et al. 1991). Caribbean fishermen commonly target both smaller and larger fishes (e.g., grunts, squirrelfishes, damselfishes, wrasses) that would be the most abundant forms associated with artificial reefs (Randall 1963; Fast 1974; Beets 1989). Other targeted fishes such as parrotfishes and surgeonfishes also seek out reef habitats for shelter and food. This is also generally true of members of the snapper and grouper families that aggregate around physical structures in offshore areas. The process of reef colonization and community building ultimately extends the potential range of some commercially and recreationally important fishes and invertebrates by providing more habitats.

In addition to fishes and invertebrates, sea turtles are attracted to these artificial habitats for food and shelter. Sea turtles forage for organisms that populate artificial reefs such as algae, anemones, sponges, and some crustaceans (Bjorndal 1997). Some top ocean predators are also attracted to shipwrecks, artificial reefs, and other structures to feed on the aggregation of prey items although marine mammals are not currently known to specifically associate with the artificial reef areas.

Unlike artificial reefs and shipwrecks that are deployed on the seafloor, other man-made structures (fish aggregating devices [FADs]) are anchored on the bottom and/or suspended throughout the water column. FADs consist of objects suspended in the water column or floated at the surface to attract fishes (Bohnsack et al. 1991). Although FADs have had varying levels of success in near and offshore applications, they have been effective in attracting pelagic fish species like tuna (yellowfin, blackfin, and skipjack), wahoo, cero mackerel, barracuda, and dolphinfish in Puerto Rican and Virgin Island waters (Beets 1989; Sea Grant College Program 1992). Artificial habitats, including FADs, enhance fish aggregation and production (Seaman and Sprague 1991).

4.4.1 Shipwrecks

Many shipwrecks are found on the Puerto Rico Platform. Merchantmen, frigates, warships, slave ships, schooners, and privateers dating from 1500 to 1825 have been sunk, lost, or run aground off Puerto Rico and the Virgin Islands. Only a small number of sailing vessels were wrecked in these waters during the sixteen and early seventeen centuries as virtually no shipping passed through or even near these waters until the mid-seventeen century, when European nations other than Spain began to establish settlements throughout the Caribbean. Subsequently, many of these ships perished in or around Puerto Rico and the Virgin Islands (Towle et al. 1976; Cardona-Bonet 1989).

From the 1833 to the present, numerous shipwrecks occurred on the insular shelf surrounding Puerto Rico and the Virgin Islands; more than 350 wrecks are located at Horseshoe Reef off Anegada (Berg and Berg 1989). Shipwrecks from the nineteenth and twentieth centuries include freighters, paddlewheel steamers, tugboats, ferries, and barges that were sunk as a result of encountering geographic and/or physiographic features (i.e., coral reefs, submerged seamounts, rocky formations), storms with treacherous seas (hurricanes), or conflicts of various wars (Simonsen 2000; Handler 2001).

Within the PROA/St. Croix OPAREA, seven shipwrecks are located (Figures 4-2 and 4-3). Many of the recent shipwrecks (e.g., RMS *Rhone* in the BVI) are popular as recreational dive sites (see section 6.4 for more information on dive site locations).

4.4.2 Artificial Reefs

An artificial reef consists of one or more submerged structures of natural or human origin deployed purposefully on the seabed to influence physical, biological, or socioeconomic processes related to living marine resources (Baine 2001). Artificial reefs are defined physically by the design and arrangement of materials used in construction as well as functionally according to their purpose (Seaman and Jensen 2000). A large number of items can and have been used for the creation of artificial reefs. Materials can include natural objects such as wood (weighted tree trunks), shells, and quarry rock or man-made objects like vehicles (automobile bodies, railroad cars, Sherman tanks), aircraft, steel-hulled vessels (Liberty ships, landing ship tanks, barges, tug boats), home appliances, discarded construction materials (concrete culverts), scrap vehicle tires, oil/gas platforms, ash byproducts (solid municipal incineration, coal/oil combustion), and prefabricated concrete structures (reef balls) (Artificial Reef Subcommittee 1997). The purpose of deploying artificial reefs in the marine environment has been to enhance artisanal and commercial fishery production/harvest, to enhance recreational activities (fishing, scuba diving, tourism), to restore/enhance water and habitat quality, to provide habitat protection and aquaculture production sites, and to control fish mortality (Seaman and Jensen 2000).

McGurrin et al. (1989) provided an excellent summary of the history of artificial reef development in the U.S. In 1984, the U.S. Congress, as it recognized the social and economic value in developing artificial reefs, passed the National Fishing Enhancement Act (NFEA) (Title II of Public Law [PL] 98-623). One of the primary directives of NFEA was the preparation of a long-term National Artificial Reef Plan (NARP). Section 202 of the act recognized the harmful effects of overfishing on fishery resources and proposed that properly designed, constructed and located artificial reefs could enhance the habitat and diversity of these fishery resources. The NARP, which is currently undergoing revision (NMFS 2002), was signed in November 1985 to provide guidance and/or criteria on various aspects of artificial reef use, including types of construction materials and planning, siting, designing, permitting, installing, maintaining, and managing artificial reefs (Gordon 1993). Many coastal states and some U.S. territories, such as Puerto Rico and Pacific Islands, have become active in the development of their own artificial reef programs. Regulation of the implementation and funding of projects was not part of the original plan, but cooperation between states/U.S. territories and federal agencies has helped in the planning and permitting of local artificial reefs (Christian 2001).

Artificial reef development in the Caribbean is dependent upon the nature of the insular shelf. Substrate, sedimentation rate, currents, topography, depth, and turbidity are some of the environmental factors essential for planning the location (west or leeward side) of small benthic artificial reefs (Goodwin and Cambers 1983; Claro and Garcia-Arteaga 1999). Small artificial reefs formed from scrap tires or concrete blocks are placed between the shore and the shelf edge (Randall 1963; Fast 1974; Hixon and Beets 1989). Floating or middle water structures (e.g., FADs) are generally utilized in areas dominated by submarine terraces and/or complex topography (e.g., northeast/southeast coast of Puerto Rico, Salt River Submarine Canyon, north coast of St. Croix).

The Department of Natural and Environmental Resources (DNER) initiated Puerto Rico's artificial reef program in 1992. Concrete pipes were the first types of artificial habitats deployed by the DNER in the area of Humacao fishing pier (Punta Santiago). These submerged structures were later replaced by reef balls (e.g., off Fajardo) as the emphasis shifted to the use of these artificial reef modules. To enhance artificial reef construction off Puerto Rico, DNER utilized square concrete culverts as substitute for the reef balls at both Humacao and Fajardo. To date, approximately 200 units (reef balls and box culverts) have been installed at these locations (Lilystrom personal communication). Before the initiation of the artificial reef program, Feigenbaum and Blair (1987) recommended the development of a site plan for artificial reefs. Benthic artificial reefs constructed of reinforced concrete structure and tires imbedded vertically in concrete were to be deployed in the offshore waters near San Juan and Ponce, Puerto Rico.

Various sunken ships, some dating from 1500, are utilized as artificial reefs on the Puerto Rico Platform and around St. Croix. The U.S. Army Corps of Engineers and U.S. Coast Guard sunk vessels to form artificial reefs off St. Croix and St. Thomas (Berg and Berg 1989), while the Navy has sunk at least 15 vessels (e.g., destroyers, amphibious transport docks, landing ship docks, and cruisers) off Puerto Rico as target ships during military maneuvers between 1970 and 1998 (Figures 4-2 and 4-3) (GMI 2002). There are currently eight artificial reefs, six of which were intentionally sunk ships, which are used as recreational dive sites (Berg and Berg 1989; Simonsen 2000; Handler 2001).

4.4.3 Fish Aggregating Devices

FADs consist of single or multiple floating structures (Samples and Hollyer 1989) that are connected to the ocean floor by ballast or anchors. These devices are designed to provide surface area at a designated height above the oceans floor, or below the ocean's surface (depending upon ocean depth at the location where the FADs are deployed). Usually prefabricated, FADs are designed to attract pelagic fish species (Klima and Wickham 1971). Deployment can be in pre-arranged alleys (rows) or in random patterns (Beets 1989; Rountree 1989). Two fundamentally different oceanic and coastal FAD devices have become established in the U.S. since the 1970s: large floating FADs and small mid-water FADs. Large floating FADs have been successfully deployed in water depths up to 1,829 m for ocean pelagic commercial and recreational fisheries. Small mid-water FADs have been used for coastal (5 km offshore) recreational fisheries in waters ranging in depths from 14 to 30 m (Rountree 1990). Incorporation of FADs in the vicinity of artificial reefs or attached to artificial reefs has been reported to improve catches of pelagic sportfishes (Stephan and Lindquist 1989) and demersal finfishes (Kellison and Sedberry 1998).

Experimental deployment of FADs were first recommended in 1986 to demonstrate and determine their feasibility for potentially increasing the commercial/recreational harvest of underutilized pelagic fishes off Puerto Rico. Initially, 14 FAD sites were designated around Puerto Rico (Feigenbaum and Blair 1987). To date, FADs have been deployed at sites off the northeast, southeast, east, and west coasts of Puerto Rico (Feigenbaum and Blair 1987; Feigenbaum et al. 1989; Berrios and Timber 1995; Lilyestrom 2002). FADs have also been installed off the south coast of St. Thomas (Beets 1989) and north coast of St. Croix (Friedlander et al. 1994).

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5.0 FISH AND FISHERIES

5.1 FISH

The PROA/St. Croix OPAREA includes both shallow water (waters < shelf break) areas adjacent to islands as well as deepwater (waters > shelf break) regions farther from the islands. Nearshore habitats include coral reefs (both fringing and patch reefs), seagrass beds, rubble, and algal beds (Mateo and Tobias 2001). Open water fish habitats, which are usually defined by depth, range from epipelagic (closest to the surface) to bathypelagic (deepest), with mesopelagic in between. Given the variety of fish habitats in the OPAREA, the fish diversity is high, as would be expected (Gilbert 1972), with well over a thousand species representing a broad taxonomic range (CFMC 1998). Overall, the fishes within the PROA/St. Croix OPAREA are typical of those found elsewhere in the Caribbean Sea (Humann 1994). None of the species within the OPAREA are listed as threatened or endangered under the ESA.

The fishes closest to shore in the OPAREA are those typically associated with Caribbean coral reefs (Humann 1994; Simonsen 2000; Handler 2001), such as snappers and grunts (Robins 1971). Surveys of nearshore waters off Puerto Rico (REEF 2002), the USVI (REEF 2002), St. Croix (Mateo and Tobias 2001), and the BVI (REEF 2002) indicated that the most abundant fishes were parrotfishes, wrasses, butterflyfishes, surgeonfishes, damselfishes, and grunts. All of these are considered to be coral reef fishes (Humann 1994). The high diversity of coral reef fishes in Puerto Rico and the Virgin Islands is maintained by the partitioning of the physical environment (Kaufman and Ebersole 1984; Shulman 1985) and food resources (Randall and Hartman 1968), as well as by behavioral associations such as cleaning symbioses (Johnson and Ruben 1988).

Some coral reef fishes are known for their spawning aggregations, in which concentrations of individuals during reproductive periods are higher than during non-reproductive periods (Domeier and Colin 1997). These events are particularly interesting from an ecological, behavioral, and fisheries perspective. Domeier and Colin (1997) elucidated two types of aggregations: transient and resident. Transient spawners, such as seabasses and snappers, move into and out of the spawning area, often coming from great distances over long periods of time. Resident spawners, such as parrotfishes, wrasses, and surgeonfishes, often spawn within or close to their home range. Recently, spawning aggregations have become a focus of fisheries managers and conservationists. As fishermen became aware of reef fish aggregations, the spawning groups were intensively targeted. This strategy not only eliminated or reduced particular stocks of fishes (Domeier and Colin 1997), but severely reduced recruitment to the next year-class.

Pelagic fish species spend their entire lives in neritic and offshore waters. Some species may be associated with particular portions of the water column, other species are capable of utilizing large portions of the water column, and yet others use different portions of the water column during various stages of their life history (Backus 1987). Pelagic fishes sometimes aggregate for feeding or breeding along ocean fronts (Govoni and Hare 2001) and currents often concentrate the eggs and larvae (Govoni and Spach 1999; Epifanio and Garvine 2001). Fish-aggregating devices (FADs) and rafts of *Sargassum* attract some species of pelagic fishes (Fedoryako 1989; Rountree 1989; Settle 1993; Moser et al. 1998). Fishes associated with the epipelagic zone (e.g., jacks, dolphinfish, mackerels, tunas, swordfish) tend to be targeted in commercial fisheries (Schwartz 1989). Many of these commercially important species are common in the PROA/St. Croix OPAREA (Humann 1994).

The Caribbean Sea has a rich abyssal fish fauna, with about 160 species representing many families that are unfamiliar except to ichthyologists (Rass 1968). A wide variety of fish species, inhabiting different habitat types, occurs within the PROA/St. Croix OPAREA. Many of the fishes, both in the coral reef and pelagic environments, are important to both commercial and recreational fisheries.

5.2 FISHERIES

In contrast to the productive temperate fishing grounds along the coastal U.S., fisheries of the Caribbean Sea differ in several ways. The tremendous diversity of coral reef fishes is a confounding factor for

efficient fishing effort. Rather than target large numbers of one or a few species, using primarily one type of fishing gear and processing a relatively uniform catch (as with the walleye pollock fishery off Alaska), Caribbean fisheries target many species, of various sizes and abundance, using a variety of gear types (Robins 1971). The spatial complexity of coral reefs makes the deployment of large nets impractical, whereas the relatively featureless benthic topography of the U.S. continental shelf (e.g., off Alaska or New England) makes the use of large otter trawl fishing gear tremendously efficient. Consequently, much of the fishing effort in the Caribbean, especially around reefs, is low-tech and small-scale, using traps and hook and line gear (Robins 1971).

Recreational fishing is tremendously popular in the Caribbean, especially in Puerto Rico and the USVI. Both residents and tourists engage in recreational fishing, particularly for billfish. Most fishing occurs on the insular shelf and due to the close proximity of deep water to shore, recreational fishermen can capture fish ordinarily that only occur great distances from shore.

The Caribbean Fishery Management Council (CFMC), along with the Puerto Rico DNER and the USVI Department of Fish and Wildlife, manages the commercial fisheries in Puerto Rico and the USVI. Fishery management plans (FMPs) have been developed for spiny lobster, shallow water coral reef fish, corals, coral reef associated plants and invertebrates, and the queen conch (CFMC 2002a). Essential fish habitat (EFH) has also been designated in the U.S. Caribbean for lifestages of 17 selected species of fish and invertebrates, six of which are managed species (CFMC 1998). EFH includes all waters and substrates (mud, sand, rock, and associated biological communities) from the shore to the EEZ; this includes all coral habitats, sub-tidal vegetation (seagrass and algal beds), and adjacent intertidal vegetation (wetlands and mangroves) (CFMC 1998). Therefore, nearly all marine waters and substrates within the PROA/St. Croix OPAREA are considered EFH.

5.2.1 Commercial Fishing

Puerto Rico and the Virgin Islands, like the rest of the Caribbean, have a small, mostly artisanal fishing industry with about 2,000 boats involved in commercial fishing (Weidner et al. 2001). Primarily targeted are bottom or demersal fishes close to shore. The narrow insular shelf, especially around Puerto Rico, and the relatively unproductive Caribbean waters are limiting to fishery effort. Heavy fishing pressure on limited resources has reduced yields in recent years (Weidner et al. 2001). The overall fisheries catch is quite small and the local markets are primarily supplied from the continental U.S. and from foreign countries. Fishermen use small boats and largely traditional fishing gear and methods (Table 5-1; Weidner et al. 2001).

Coral reef fishes comprise the largest commercial fishery in the PROA/St. Croix OPAREA and vicinity by both tonnage and economic value landed (Table 5-1). The commercial coral reef fish fishery can be loosely divided into shallow water and deepwater components. The relatively shallow water of the Puerto Rico Platform provides abundant habitat for reef fishes around Puerto Rico and the Virgin Islands. Fishermen target many of the fish species associated with coral reefs; these fishes usually include snappers, groupers, and parrotfishes (CFMC 2002b) but can sometimes include squirrelfishes, grunts, and surgeonfishes (FAO 1993). The fishermen are not particularly discriminating about their catch and many of the fish are consumed locally. The geographical extent of the shallow water coral reef-fish fishery roughly approximates the boundaries of the Puerto Rico Platform (Figure 5-1). This fishery is generally considered as separate from those operating along the slopes of the island platforms or on deeper banks (FAO 1993). This distinction is a convenience based more on gear-type than on the discreteness of the fishery resources, which are distributed continuously along the depth gradient (FAO 1993). The shallow water reef fish fishery is primarily artisanal (Mahon 1987) and employs the majority of fishermen in the Caribbean (FAO 1993). Fishermen often work part-time, travel short distances to reach fishing grounds, use small open boats with outboard engines, and usually use traps and handlines (FAO 1993). It is widely accepted that shallow water reef fish resources are overexploited, given the scarcity of large individual fishes and the paucity of larger fish species (Mahon 1987; Appeldoorn et al. 1992). In particular, the grouper fishery resources of Puerto Rico are in decline (Matos-Caraballo 1997). This decline is partly due to the targeting of spawning aggregations, such as that of tiger groupers off Vieques Island (Matos-Caraballo and Posada 2000).

Table 5-1. Major commercial/artisanal fisheries of the PROA/St. Croix OPAREA and vicinity including their seasons, gear used, landings, and economic value. Fisheries are ranked by tonnage landed in 2000.

FISHERY[a]	SEASON[a]	GEAR[a]	TONS[b]	VALUE[b]
Coral Reef				
Snappers, Groupers, Grunts, Parrotfishes, Squirrelfishes, Goatfishes, and Surgeonfishes	Year-round	**Shelf:** Traps and Handlines **Slope:** Traps, Handlines, and Bottom Longlines	1,190	$5,029,454
Pelagic				
Tunas and Mackerels, Dolphinfish, Jacks, Barracuda, Herrings, Sardines, and Sharks	Year-round	Troll Lines, Hand lines, Longlines, Traps, Gillnets, and Beach Seines	297	$982,824
Swordfish				
Swordfish (Some Bycatch Consisting of Billfishes, Tunas, and Sharks)	Late November to June	Longlines, Troll Lines, and Some Handlines	155	$464,631
Conch				
Queen Conch and other Marine Gastropods	Winter, Spring, and Fall	Hand Collection Via Scuba and Free Diving	125	$583,891
Spiny Lobster				
Caribbean Spiny Lobster and Slipper Lobster	Year-round	Snares Via Free Diving, Pots, and Traps	120	$1,222,101
Reef Organism/Aquarium Trade				
Live Fishes, Invertebrates, and Algae (No Live Hard Corals)	Year-round	Various Hand Collection Techniques Via Scuba and Free Diving	NA	NA

[a] Sources: Mahon 1987; Appeldoorn and Meyers 1993; FAO 1993; Weidner et al. 2001
[b] Source: NMFS 2001

NA = Not Available

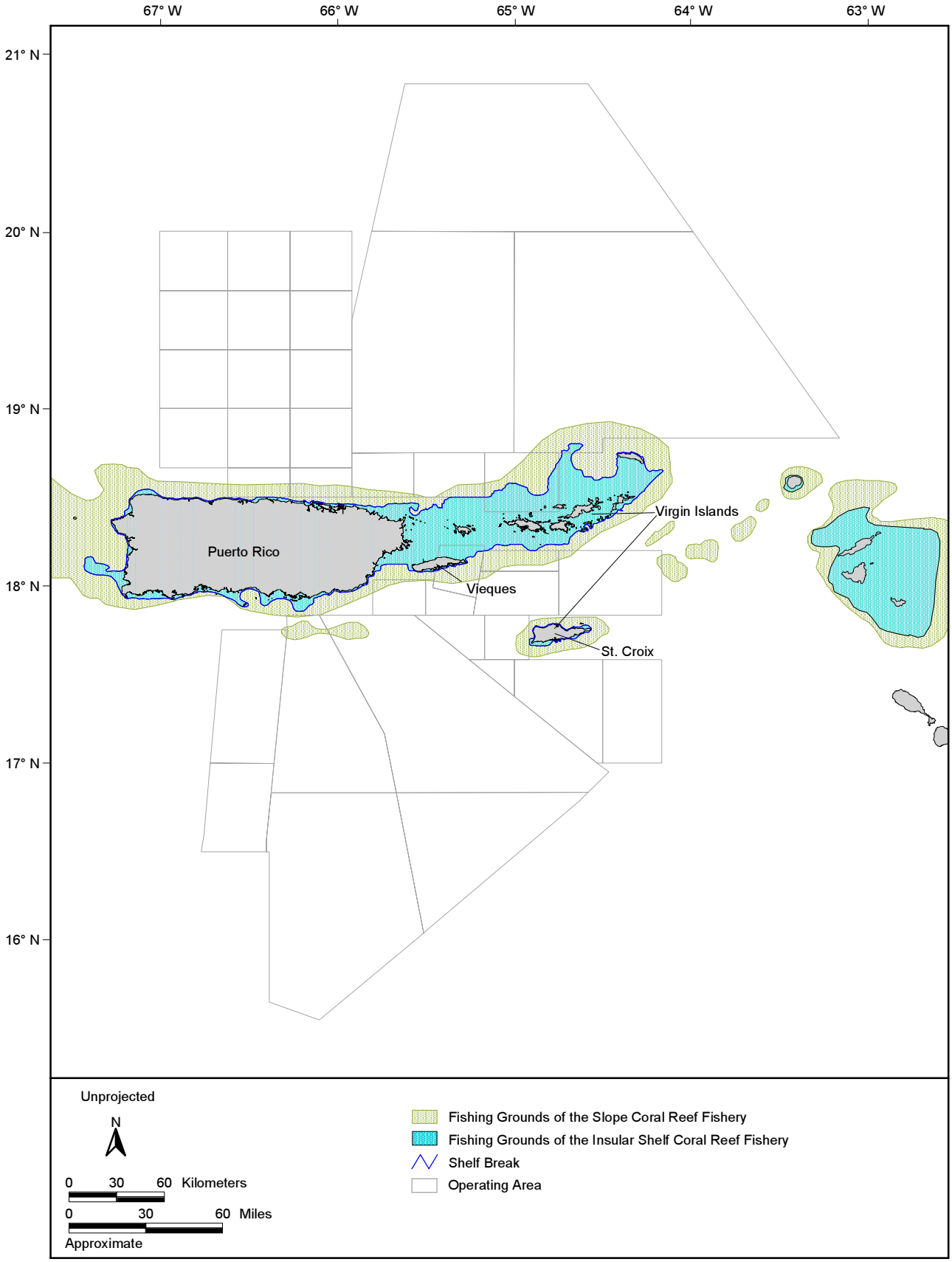

Figure 5-1. Estimated year-round fishing grounds of the commercial/artisanal demersal shelf and slope coral reef fisheries in the PROA/St. Croix OPAREA and vicinity. Map adapted from: Appeldoorn et al. (1987), Mahon (1987), Appeldoorn and Meyers (1993), and Mahon (1993).

Reef fishes are also caught in the deeper water over the Puerto Rico Platform's slope and around deeper banks (Figure 5-1). Fishes of the snapper-grouper complex are the primary targets. In contrast with the shallow water reef-fish fishermen, the deepwater reef-fish fishermen more typically target larger species of better market quality; these more valuable fishes are then sold to processors or restaurants, or are exported (FAO 1993). Although both shallow and deepwater coral reef fishermen utilize traps and handlines, longlines are sometimes used in deeper water. Fishermen fishing in deeper water tend to have larger boats that are better equipped with such gear as depth sounders and trap haulers (FAO 1993). As with fishes in shallower water, the deepwater fishes are heavily exploited and their populations are in danger of depletion (Mahon 1987).

Other than coral reef fishes, the other major group of fishes targeted by fishermen in Puerto Rico and the Virgin Islands are pelagic fishes (Table 5-1). Pelagic fishes that are prized by fishermen include tunas, mackerels, barracuda, dolphinfish, jacks, herrings, sardines, and sharks. Pelagic fishes are often considered to be "open ocean" fishes occurring at some distance from shore. However, the close proximity of deep water to the shores of Puerto Rico and the Virgin Islands allows coastal fishermen to exploit pelagic species. Consequently, the fishery for large pelagic fishes occurs relatively close to shore (Figure 5-2). The primary gear type used in pelagic fisheries off Puerto Rico is the troll line, with 100% of dolphinfish, about 90% of commercial tuna and mackerel, and about 75% of barracuda harvested with this gear (Appeldoorn and Meyers 1993). Due to the very narrow insular shelf, some of the smaller pelagic species (e.g., herrings, sardines) sometimes approach very close to shore and can actually be harvested with beach seines. Jacks are harvested by handlines, beach seines, gillnets, and fish traps (Appeldoorn and Meyers 1993). The use of longlines in the OPAREA, especially by foreign vessels fishing for tuna, has increased in recent years (Mahon 1993). The annual landings in Puerto Rico of pelagic resources has fluctuated dramatically from year to year (Appeldoorn and Meyers 1993); this might be due to migration patterns of pelagic fishes or a lack of a standardized approach to collecting data. For example, barracuda landings for Puerto Rico peaked in 1980 at 43.1 tons, and from 1987 through 1989 averaged less than nine tons. Dolphinfish landings were 37.3 tons in 1980, declined to 6.7 tons in 1984, and increased to 31.1 tons in both 1988 and 1989 (Appeldoorn and Meyers 1993).

Another group of pelagic fishes important both commercially and recreationally are the billfish. Fishes belonging to the families Istiophoridae (sailfish, white marlin, blue marlin, longbill spearfish) and Xiphiidae (swordfish) are collectively known as billfish because of the long pointy extension of their upper jaw. Local fishermen catch minor quantities of billfish (except swordfish) as part of the generalized pelagic fish fishery (Figure 5-2). However, an important swordfish resource does occur in the Caribbean, mainly off Puerto Rico (Table 5-1). Due to the commercial value of swordfish, fishermen from outside of the Caribbean region sometimes target swordfish in waters that partly include the PROA/St. Croix OPAREA (Figure 5-3; Witzell 1996; Weidner et al. 2001). Continental U.S. longline fishermen deploy commercial longliners for swordfish in the northwestern Caribbean Sea. The continental longliners work out of San Juan on a seasonal basis. When the catches decline off the northeastern U.S. coast in November, as many as 70 mainland longliners shift their operations south to the Caribbean Sea and adjacent areas. While mainland longliners were very active in the mid-1990s, the Caribbean area operations have declined, and in 2001 only a few U.S. longliners worked out of San Juan (Weidner et al. 2001).

One of the fishery resources most associated with the Caribbean is the queen conch (Table 5-1). The fishery for conch is the second most important in the Lesser Antilles, with 125 tons landed in 2000 in the PROA/St. Croix OPAREA (NMFS 2001). Conch occurs most abundantly in sheltered sandy and seagrass habitats (Mahon 1987). Consequently, fishing grounds for conch are in shallow water (Figure 5-4). In Puerto Rico, conch are taken almost exclusively by scuba divers using small boats, while in the Virgin Islands free divers (i.e., breath-hold divers not using scuba) take conch in shallow water and scuba divers collect conch in deeper water (FAO 1993). In the BVI, recreational divers take an appreciable portion of the conch stock (FAO 1993). Conch are distributed patchily throughout the Caribbean Sea. For example, most conch in Puerto Rico are collected along the west coast (Mahon 1987). St. Croix has a commercial conch fishery concentrated along the west and northwest coasts (Mahon 1987). There is currently no fishery in St. Thomas or St. John due to a significant decline in the stock (CFMC and CFRAMP 1999); conch historically have been found on the north and south sides of these two islands. In the BVIs, most conchs are taken along Horseshoe Reef near Anegada Island (Mahon 1987). Given that most conch

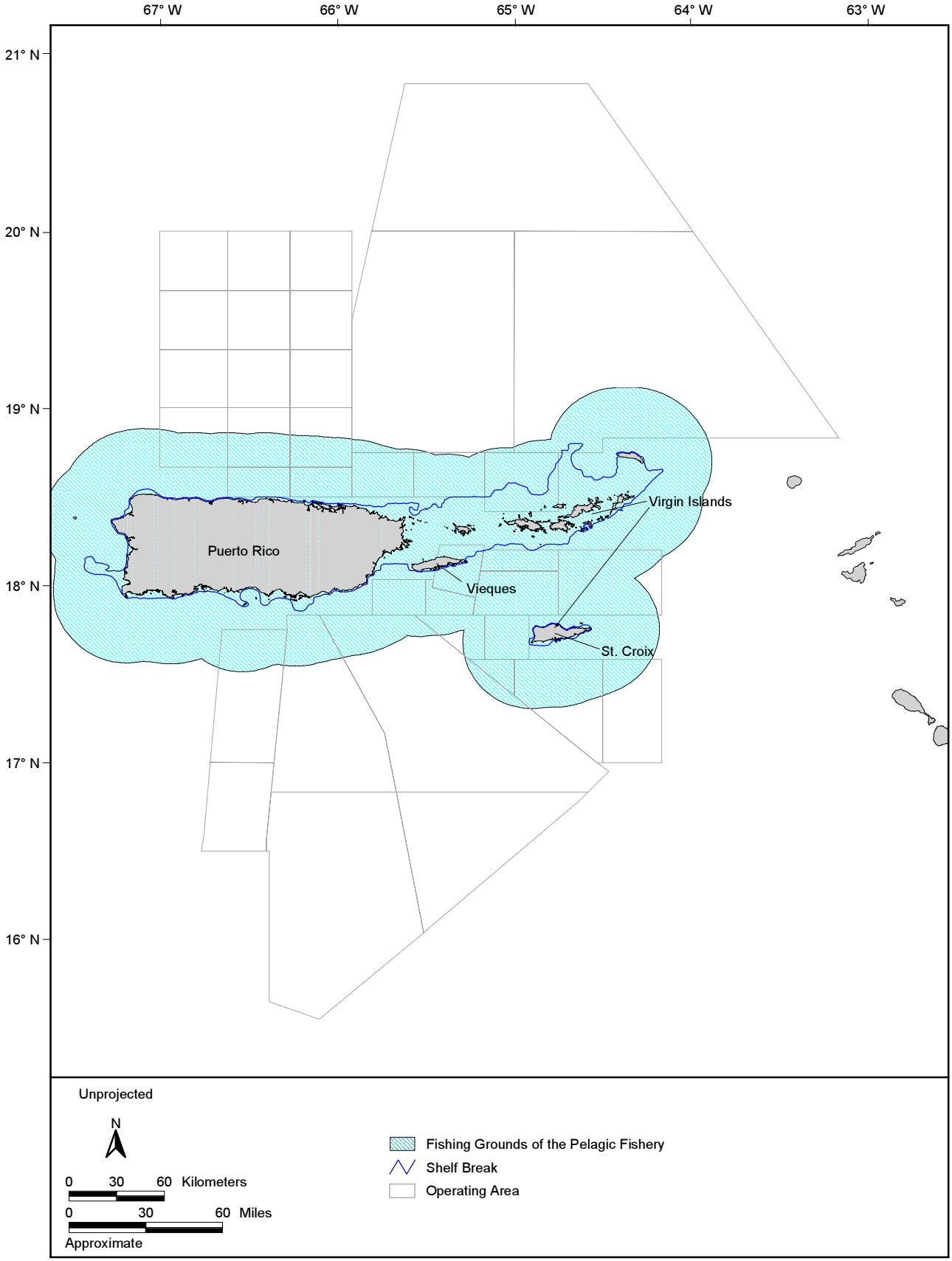

Figure 5-2. Estimated year-round fishing grounds of the commercial pelagic fishery in the PROA/St. Croix OPAREA and vicinity. Map adapted from: Hunte (1987), Mahon (1987), Mahon and Mahon (1987), Appeldoorn and Meyers (1993), Mahon (1993), and NMFS (2001).

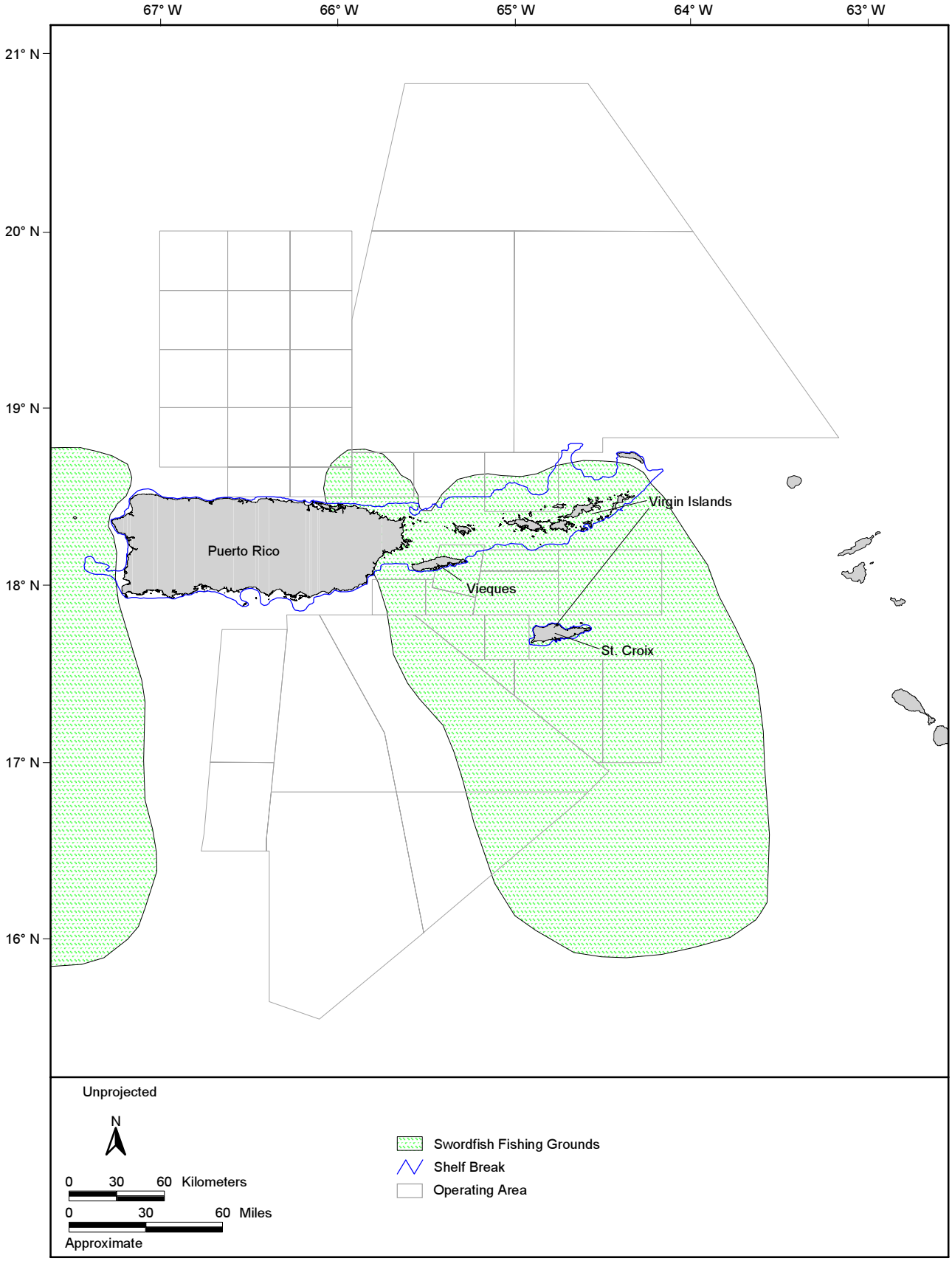

Figure 5-3. Estimated seasonal (November through April) fishing grounds of the commercial swordfish fishery in the PROA/St. Croix OPAREA and vicinity. Map adapted from: Witzell (1996) and Weidner et al. (2001).

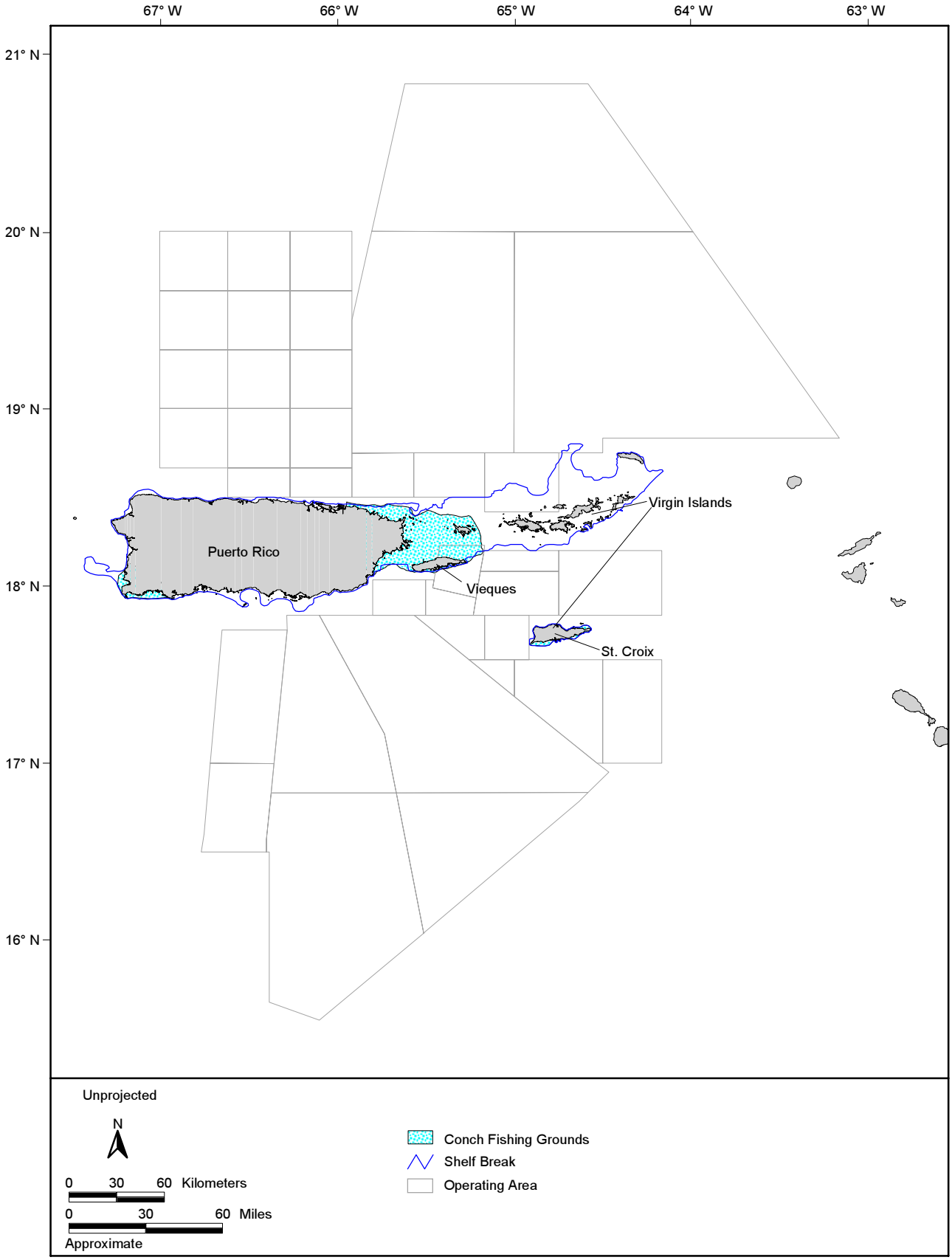

Figure 5-4. Estimated seasonal (winter, spring, and fall) fishing grounds of the commercial/artisanal conch fishery in the PROA/St. Croix OPAREA and vicinity. Fishery is closed in the summer. Map adapted from: Appeldoorn et al. (1987), Mahon (1987), Appeldoorn and Meyers (1993), Mahon (1993), and CFMC and CFRAMP (1999).

stocks are considered fully or overexploited (Mahon 1987), some management strategies have been implemented. For example, in Puerto Rico there are size limits, closed seasons, quota and bag limits, and gear restrictions (CFMC 2002c).

Perhaps the fishery resource for which the Caribbean region is best known is the spiny lobster (Table 5-1). Spiny lobster is the most important fishery in the Lesser Antilles (FAO 1993), with 120 tons landed in 2000 at a value of one million dollars (NMFS 2001). Spiny lobsters tend to hide in shallow water coral reef crevices (CFMC 1981; Mahon 1987). Consequently, the fishery is concentrated in nearshore waters of the Puerto Rico Platform (Figure 5-5). Fishermen employ small boats to reach spiny lobster fishing grounds (FAO 1993). Free divers, some using snares, take lobsters in the shallower areas (FAO 1993). In deeper water beyond the limit of free divers, fishermen utilize baited pots and traps (Mahon 1987; FAO 1993). The popularity of spiny lobsters has resulted in widespread overfishing. Some of the management strategies include a size limit (carapace length at least nine cm) and gear restrictions (CFMC 2002d).

The collection of coral was a common activity with a long history in Puerto Rico (CFMC 1994). Corals were harvested and prepared for sale as ornamental pieces, while coral fragments and small mollusk shells were often incorporated into local craftwork and jewelry in Puerto Rico and the Virgin Islands (CFMC 1994). Widespread collecting of corals ceased in 1979 (CFMC 1994). The taking of reef-associated organisms for the aquarium trade (Table 5-1) is a relatively new activity that began in about 1970 in Puerto Rico. This industry expanded rapidly in the late 1980s in Puerto Rico due to increased demand (much of it from hobbyists in the U.S. and western Europe), improvements in technology for maintaining reef organisms in home aquaria, excellent transportation facilities at San Juan airport, and restrictions elsewhere (e.g., Florida) on the taking of such resources (CFMC 1994). Puerto Rico is now considered to be one of the major sources worldwide for Caribbean coral reef organisms. The collection of coral reef organisms in Puerto Rico and the Virgin Islands occurs, quite naturally, where coral reefs occur (Figure 5-6). Although few regulations have existed to manage this industry, collection permits are now required (CFMC 2002e).

5.2.2 Recreational Fishing

Puerto Rico and the Virgin Islands have a massive fleet of recreational boats that may well exceed that of all the other Caribbean islands combined (Weidner et al. 2001). Estimates for Puerto Rico of as many as 55,000 recreational boats that are used at least occasionally for fishing have been made (Weidner et al. 2001). Approximately 5,000 recreational vessels are equipped to fish for pelagic species and about 1,000 of these vessels are used frequently. Most recreational boats are 10 to 14 m in length and made of fiberglass while some boats are over 18 m (Weidner et al. 2001).

Recreational fishing is important to both residents and tourists (Weidner et al. 2001). Anglers began developing the recreational fishery in Puerto Rico during the 1950s. Much of the early interest focused on billfish, which continue to dominate recreational fisheries. While there is some recreational fishing for dolphinfish and wahoo, there is limited interest in reef fish (Weidner et al. 2001). Consequently, many of the recreational fishing grounds are concentrated along the insular shelf slope (Figure 5-7) where there is a greater likelihood of encountering pelagic species. Recreational fishermen do not concentrate in the shallow water near coral reefs, as do some commercial fisheries. Recreational angling is conducted throughout the year, declining substantially during the colder months of January and February (Weidner et al. 2001).

Billfish are a major focus of recreational fisheries in Puerto Rico, more so than along the mainland U.S. In fact, Puerto Rico sometimes bills itself as the blue marlin capital of the world (Powercruising.com 2002). In both regions, however, participation in recreational billfish fishing continues to grow. In the U.S. Atlantic and Caribbean, over 7,000 anglers made over 100,000 billfish fishing trips in 1990 (Clark et al. 1999). Competitive billfish tournaments have grown to number over 800 in the U.S. and Caribbean. The 1988 fisheries management plan for Atlantic billfishes prohibits the commercial sale of all billfishes except swordfish (Clark et al. 1999). The intent of the regulation is to encourage recreational fishing for billfishes, along with the economic benefits derived from such activity. The economic impact of non-resident billfish anglers to the Puerto Rican economy was estimated at $4.75 million and was responsible for over 200

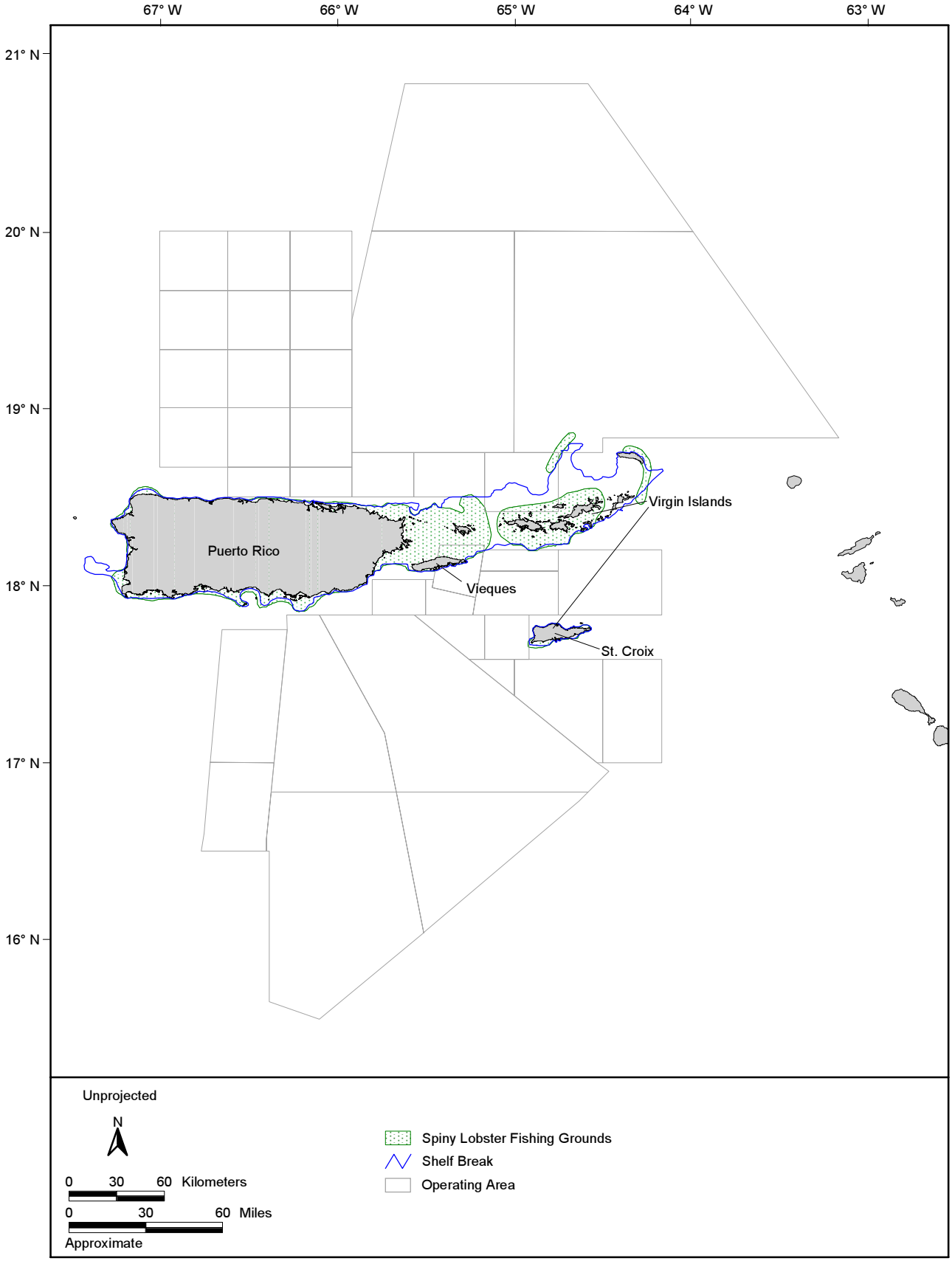

Figure 5-5. Estimated year-round fishing grounds of the commercial/artisanal spiny lobster fishery in the PROA/St. Croix OPAREA and vicinity. Map adapted from: Appeldoorn et al. (1987), Mahon (1987), Appeldoorn and Meyers (1993), and Mahon (1993).

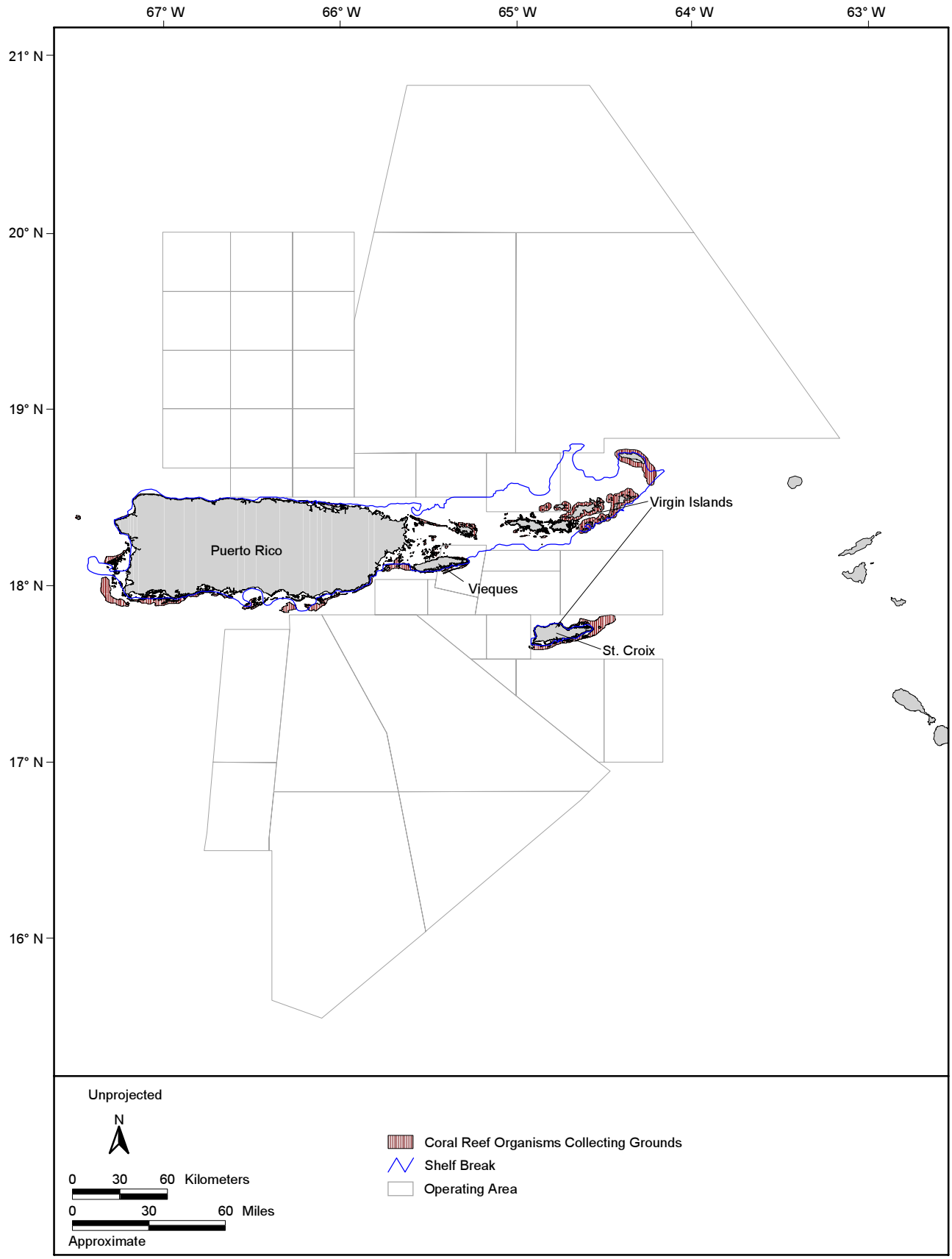

Figure 5-6. Estimated year-round collecting grounds in the PROA/St. Croix OPAREA and vicinity of coral reef organisms for the commercial aquarium trade. Source data: NOS (2001a). Source map (scanned): Spalding et al. (2001). Source information: CFMC (1994).

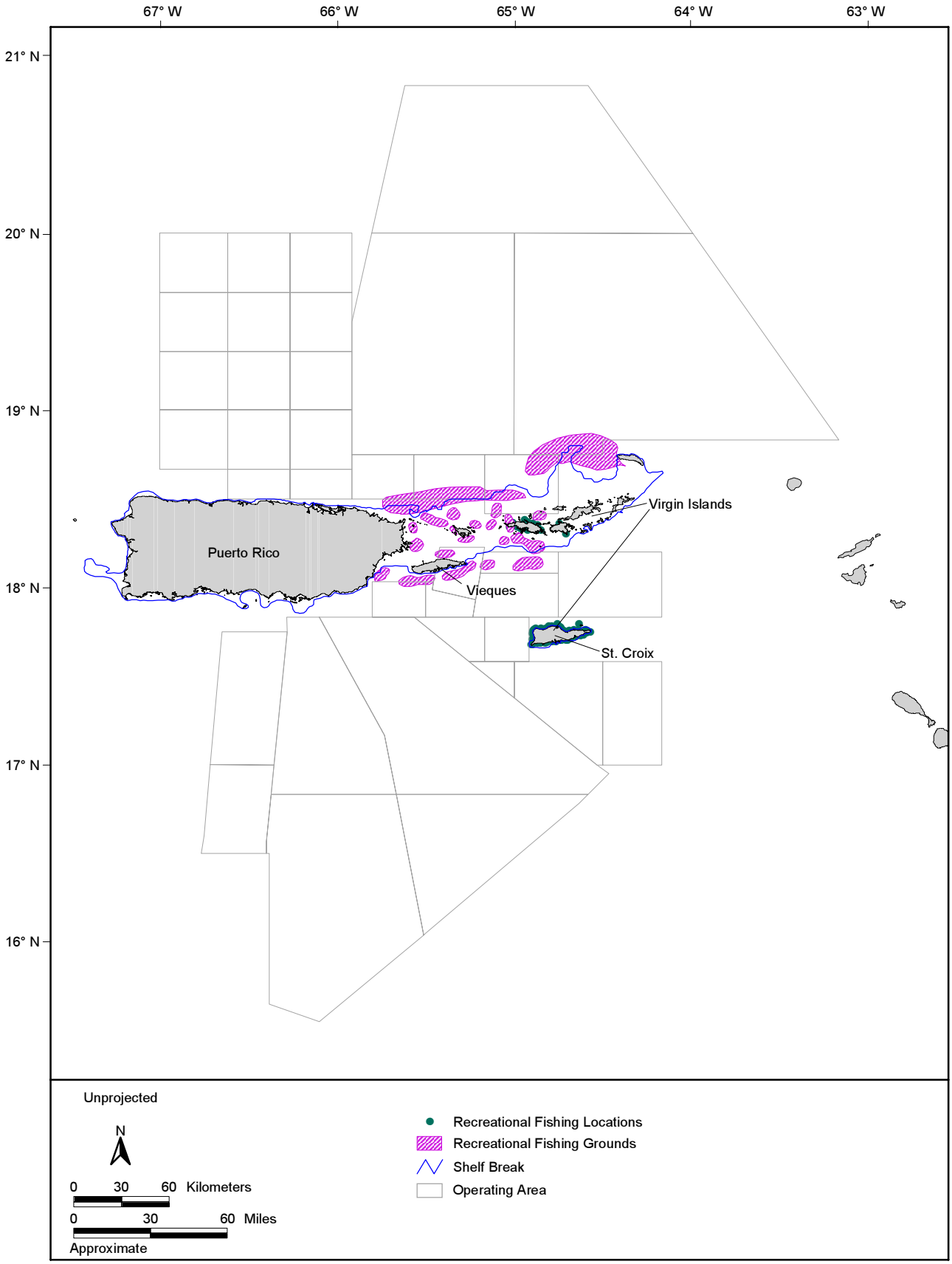

Figure 5-7. Common year-round recreational fishing grounds and locations in the PROA/St. Croix OPAREA and vicinity. Source data: NOS (2001b). Map adapted from: Waterproof Charts, Inc. (1998).

jobs (Clark et al. 1999). Despite the economic value of billfish fisheries and the promotion of catch-and-release fishing, recreational billfish catch rates have been declining (Weidner et al. 2001).

Recreational fishermen regularly participate in many Puerto Rican fishing tournaments as well as tournaments held on neighboring islands, especially in the USVI and BVI (Tables 5-2 and 5-3; Weidner et al. 2001). In Puerto Rico, there are about 25 local tournaments and one large international tournament per year. Most of these tournaments focus on billfish, with 15 to 20 tournaments targeting blue marlin (Weidner et al. 2001). The leading tournament is the Club Nautico de San Juan International Billfish Tournament, usually held in August or September. This tournament is one of the largest in the Caribbean region. Another important tournament is the Club Nautico Arecibo Sailfish Tournament held in November. Given the close proximity of deep water to Puerto Rico and the Virgin Islands, fishermen participating in tournaments do not have to travel excessive distances to reach areas where billfish can be caught (Figure 5-8).

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Table 5-2. Recreational fishing tournaments that occurred in the PROA/St. Croix OPAREA throughout 2000 and 2001.

	WEIGH-IN LOCATION		
EVENT DATE	City/Island	Island Group	EVENT NAME
Winter			
January 1	St. Croix	USVI	The Millenium
February 10-11	Santurce	PR	Congrejos Yacht Club Dorado
February 24	San Juan	PR	Puerto Rico Light Tackle Anglers
February 25	St. Thomas	USVI	St. Thomas Sweetheart's Fishing Tournament
March 1-3	Parguera	PR	Club Nautico Parguera/Lajas Tournament
March 3	St. Croix	USVI	Annual St. Croix Golden Hook Dolphin Fishing Tournament
March 9-11	Boqueron	PR	Club Nautico de la Parguera Dorado Tournament
March 15-17	Ponce	PR	Ponce Yacht and Fishing Club Tournament
March 30-April 1	Jost Van Dyke Island	BVI	Jost Van Dyke Fishing Tournament
Spring			
April 5-7	Ponce	PR	Club Deportivo Tournament
April 8	St. Thomas	USVI	Dolphin Fishing Tournament
April 14	San Juan	PR	Puerto Rico Light Tackle Anglers - Torneo del Income (April)
April 26-28	Ponce	PR	Torneo de Pesca Interclub del Caribe
April 28-30	Boqueron	PR	Club Nautico de la Parguera Marlin Tournament
May 4-5	Parguera	PR	Clasico Aguja Azul
May 6	St. Thomas	USVI	Mother's Day Fishing Tournament
May 20-21	St. Croix	USVI	Annual St. Croix Golden Hook Guys and Gals Shootout Fishing Tournament
May 26-28	St. Thomas	USVI	Virgin Islands Gamefishing Club Anegada
June 3	Anegada	BVI	Anegada Reef Hotel Fishing Tournament
June 11	St. Thomas	USVI	Father's Day Fishing Tournament
June 14-17	St. Thomas	USVI	Virgin Islands Gamefishing Club - June Moon
June 21-23	Arecibo	PR	Club Nautico Arecibo Tournament
June 22-23	Tortola	BVI	Summer Solstis Fishing Tournament
June 22-24	Carolina	PR	Torneo Nacional Asoc Pesca Deportiva
June 30-July 2	San Juan	PR	Torneo Millonario de Aguja Azul
Summer			
July 1	Beef Island	BVI	Fisherman's Day Fishing Tournament
July 1-4	Cerro Gordo	PR	Vigesimo Tercer Clasico Aguja Azul
July 5-8	St. Thomas	USVI	US Virgin Islands July 4 Open
July 6-8	Arecibo	PR	Ladies National Blue Marlin Tournament–Club Nautico de Arecibo
July 13-16	Cerro Gordo	PR	Torneo Interclub Aguja Azul
July 16	St. Thomas	USVI	Bastille Day Fishing Tournament (Inshore Category)
July 28-30	Arecibo	PR	Arecibo Outboard Club
August 1-5	St. Thomas	USVI	USVI Open Atlantic Blue Marlin Tournament
August 3-5	Santurce	PR	Annual Congrejas Yacht Club Interclub del Caribe
August 5-6	Arecibo	PR	Clasico Aguja Azul - Club Nautico de Arecibo
August 9	Tortola	BVI	Carrot Bay Fisherman's Tournament

Table 5-2. Continued

EVENT DATE	Weigh-In Location City/Island	Island Group	Event Name
August 11-13	St. Croix	USVI	Goldenhook Challenge
August 12-16	St. Thomas	USVI	USVI Open Atlantic Blue Marlin (Boy Scouts)
August 12-17	Virgin Gorda	BVI	Virgin Gorda International Marlin Week
August 17-19	Guaynabo	PR	Torneo Millonario de Aguja Azul
August 19-20	Cerro Gordo	PR	Torneo de la Amistad
August 22-24	Carolina	PR	Cangrejos Yacht and Fishing Club Tournament
August 24-26	Arecibo	PR	Clasico Aguja Azul - Club Nautico de Arecibo
September 1-2	St. Thomas	USVI	Inshore Fishing Tournament
September 3-10	San Juan	PR	International Billfish Tournament - Club Nautico de San Juan
September 6-8	Tortola	BVI	BVI September Game Fish Tournament
September 13-15	Carolina	PR	Puerto Rico Light Tackle Tournament
September 15-17	Boqueron	PR	Club Nautico de Boqueron
September 16-17	St. Croix	USVI	Annual St. Croix Golden Hook Marlin Fishing Tournament
September 22-23	Mayaguez	PR	Club Nautico-Mayaguez (Formerly 531)
September 26-29	Joyuda	PR	Club Deportivo del Oeste
September 29-30	St. Croix	USVI	Goldenhook Challenge
Fall			
October 4-7	Mayaguez	PR	International Light Tackle Blue Marlin - Club Deportiva del Oeste
October 5-6	Tortola	BVI	Annual October Wahoo Festival
November 3-5	San Juan	PR	Puerto Rico Light Tackle Anglers - Fall/Winter
November 10-12	Arecibo	PR	Club Nautico de Arecibo/Sailfish Tournament
November 12	St. Thomas	USVI	St. Thomas Wahoo Fishing Tournament
November 15	Arecibo	PR	Arecibo Outboard Club
November 18-19	St. Croix	USVI	Annual St. Croix Golden Hook Wahoo Fishing Tournament
November 25	Tortola	BVI	Golden Gaff Tournament
December 9	Carolina	PR	Vistamar Marina Fishing Team Tournament

Sources: Mateo 2001; Britishvirginislands.com 2002; BTN 2002, DNER 2002; IGFA 2002; InTheBite.com. 2002; Limin Times 2002; NMFS 2002; USVI-Info.com 2002; Ultimate BVI 2002; WhereToStay.com. 2002; WorldBillfishSeries.com 2002

Table 5-3. Number of offshore recreational fishing tournaments per season in the PROA/St. Croix OPAREA held during 2000 and 2001.

Weigh-in Location	Winter	Spring	Summer	Fall	Total
Anegada, BVI	-	1	-	-	1
Beef Island, BVI	-	-	1	-	1
Jost Van Dyke, BVI	1	-	-	-	1
Tortola, BVI	-	1	2	2	5
Virgin Gorda, BVI	-	-	1	-	1
Arecibo, PR	-	1	4	2	7
Boqueron, PR	1	1	1	-	3
Carolina, PR	-	1	2	1	4
Cerro Gordo, PR	-	-	3	-	3
Joyuda, PR	-	-	1	-	1
Mayaguez	-	-	1	1	2
Parguera, PR	1	1	2	-	4
Ponce, PR	1	2	-	-	3
San Juan, PR	1	2	-	1	4
Santurce, PR	1	-	1	-	2
St. Croix, USVI	2	1	3	1	7
St. Thomas, USVI	1	5	5	1	12
Total	**9**	**16**	**27**	**9**	**61**

Sources: Mateo 2001; Britishvirginislands.com 2002; BTN 2002, DNER 2002; IGFA 2002; InTheBite.com. 2002; Limin Times 2002; NMFS 2002; Ultimate BVI 2002; USVI-Info.com 2002; WhereToStay.com. 2002; WorldBillfishSeries.com 2002

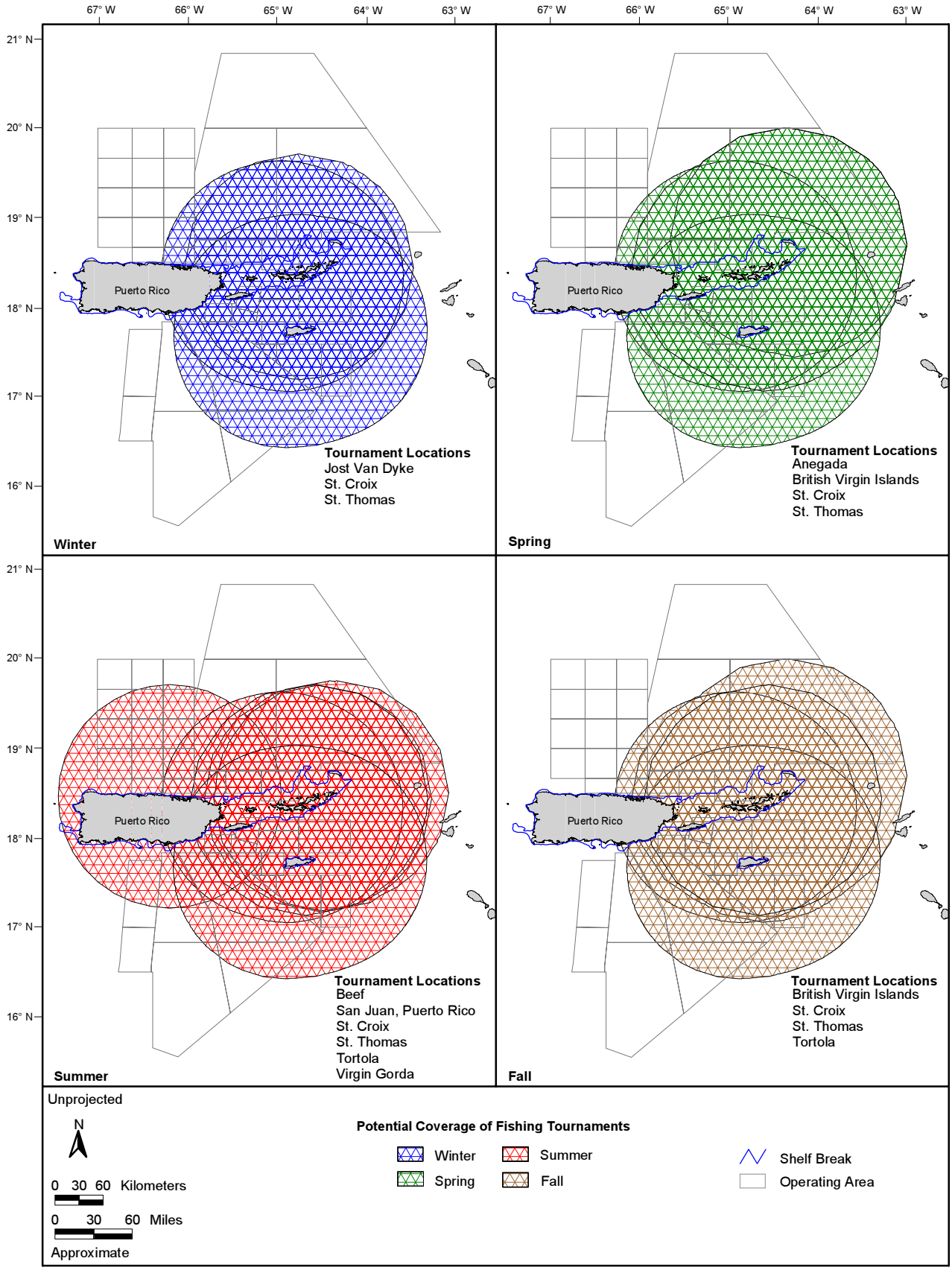

Figure 5-8. Potential area covered by recreational fishing tournament participants in the PROA/St. Croix OPAREA and vicinity by season. The estimated area covered by participants is a radius of 75 NM from the tournament origin. Map adapted from: USVI Department of Fish and Wildlife (2001), Britishvirginislands.com (2002), BTN (2002), IGFA (2002), USVI-info.com (2002), Wheretostay.com (2002), and WorldBillfishSeries.com (2002).

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6.0 ADDITIONAL CONSIDERATIONS

6.1 U.S. TERRITORIAL WATERS, CONTIGUOUS ZONE, AND EXCLUSIVE ECONOMIC ZONE

Although the U.S. and other nations historically used 3 NM as their seaward territorial limit, some American states, such as Texas, or U.S. commonwealth territories, such as Puerto Rico, have historical seaward boundaries of 3 marine leagues or 9 NM. These territorial limits were measured from the baseline of each nation or state. The U.S. has traditionally used the "rule of the tidemark" as the baseline from which to measure the width of its territorial waters. This baseline coincides with the low-water/tide line found along the shore and is often termed the "normal" baseline (Kapoor and Kerr 1986; Prescott 1987). At the mouths of bays, rivers, or other areas where the coastline is not continuous, a straight baseline is drawn over the coastal feature. Rather than use the normal baseline, an increasing number of countries use either the straight baseline or archipelagic baseline system from which to measure their territorial waters (Kapoor and Kerr 1986; Prescott 1987). In 1982, the Law of the Sea Convention established another type of baseline for island nations. Islands situated on atolls or islands with fringing coral reefs, such as many of the U.S. Virgin Islands (USVI), use the seaward low-water line of the reef as their baseline (Reed 2000).

The 3 NM limit was the standard until the later half of the twentieth century when the extent of the U.S. territorial waters was redefined. In 1945, President Truman issued Proclamation Number 2667 claiming jurisdiction and control over all the natural resources of the seabed and subsoil of the entire continental shelf adjacent to the coasts of the U.S. Jurisdiction or control of the waters overlying the U.S. continental shelf was not included in Truman's Presidential Proclamation. President Truman also issued Proclamation 2668 in 1945, which established conservation zones in areas of the high seas adjacent to the U.S. coasts. These conservation zones extended U.S. protection to coastal fishery resources that had been developed or would be developed in waters contiguous to the U.S. In 1953, Proclamation Number 2667 was nullified and replaced by the Outer Continental Shelf (OCS) Act (Table 6-1). The OCS Act placed the subsoil and seabed of the OCS under U.S. jurisdiction. Section 1331 of this act defines the OCS as "…all submerged lands lying seaward and outside of the area of lands beneath navigable waters as defined in section 1301 of this title…" (DOALOS et al. 2001). As with Proclamation Number 2667, the OCS Act did not give the U.S. authority over the waters above the continental shelf seabed, leaving them open to navigation and fishing.

Following the trend established in the U.N., the U.S., with its 1976 Fishery Conservation and Management Act (FCMA), established a 200 NM fishery conservation zone extending outward from its baselines or contiguous to its territorial seas. This 200 NM zone was designed to protect and conserve the fisheries of the U.S and its territories. When the fishery conservation zone, established by the FCMA, went into effect in April of 1977, the U.S. formally claimed the 200 NM fishery conservation zone in which it exercises exclusive fishery management authority. In the eastern Caribbean Sea, however, the U.S. territories have foreign neighbors that are located less than 400 NM away. Pending the establishment of permanent maritime boundaries by treaty or agreement with these nations, the FCMA set forth fishery limits based on a median line drawn equidistantly between two nations where a 200 NM limit is not possible (DoS 1977). At nearly the same time, the governor of the British Virgin Islands (BVI) also recognized the importance of protecting their fishery assets by establishing a fisheries zone contiguous to the territorial waters of the BVI (DoS 1994).

A 1978 treaty between the governments of the U.S. and Venezuela formally established the maritime boundaries between Venezuela and Puerto Rico/USVI in the Caribbean Sea (treaty ratified and entered into force in 1980; DoS 1986). The equidistant treaty boundary was nearly identical to that initially established by the FCMA (DoS 1977, 1986). The Reciprocal Fisheries Agreement of 1979 began the Caribbean boundary formalization process between the U.S. and the United Kingdom (U.K.) (entered into force in 1983). The agreement between the two nations confirmed their common approach of using an equidistant line to separate the Caribbean fishery extent of Puerto Rico/USVI and the BVI (DoS 1994). Furthermore, the U.K. extended the fishery limits of its Caribbean island nation of Anguilla to 200 NM in 1981 (DoS 1994).

Table 6-1. Timeline detailing the establishment of U.S. jurisdiction and maritime boundaries in the eastern Caribbean Sea by treaty, legislation, and presidential proclamation.

- **From Antiquity to the Early Twentieth Century:** nations individually established seaward boundaries of 3 to 9 NM under the "cannon shot" concept.
- **1945–Truman Presidential Proclamation Number 2667 on the Continental Shelf:** for the purpose of conserving and utilizing natural resources, the U.S. claimed jurisdiction and control of the subsoil and seabed of the continental shelf contiguous to its coast. The waters overlying the continental shelf were not affected.
- **1945–Truman Presidential Proclamation Number 2668 on Coastal Fisheries:** conservation zones were established in areas of the high seas contiguous to U.S. coasts for the purpose of protecting coastal fishery resources.
- **1953–Outer Continental Shelf Act:** the subsoil and seabed of the outer continental shelf (OCS) was declared to be under U.S. jurisdiction, control, and power. The waters overlying the OCS were not affected by this act, so fishing and navigation were unrestricted. This act nullified Presidential Proclamation Number 2667 (67 Stat. 462, 43 U.S.C. 1331 et seq.).
- **1958–United Nations (U.N.) Convention on the Law of the Sea I:** the U.N. convened the first international conference on maritime boundaries.
- **1960–U.N. Convention on the Law of the Sea II:** the second U.N. conference convened on international maritime boundaries.
- **1973–U.N. Convention on the Law of the Sea III:** the third U.N. conference convened on international maritime boundaries.
- **1976–Fishery Conservation and Management Act:** this legislation established a fishery conservation zone extending 200 NM from U.S. baselines, except in several areas such as the Caribbean Sea, where to the west, south, and east of Puerto Rico and the USVI, the limit of the fishery conservation zone was determined by geodetic or straight lines connecting points of latitude and longitude that were delineated in the act.
- **1977–Proclamation Number 4 of the Governor of the British Virgin Islands:** a fisheries zone was established contiguous to the territorial sea of the BVI.
- **1977–Fishery Conservation and Management Act:** the fishery conservation zone, established by the 1976 Fishery Conservation and Management Act, went into effect.
- **1978–Maritime Boundary Treaty:** this treaty between the governments of the U.S. and Venezuela established the maritime boundary between Puerto Rico/USVI and Venezuela as geodetic lines that connected the points of latitude and longitude that were listed in the treaty.
- **1979–Reciprocal Fisheries Agreement:** the governments of the U.S and U.K. signed this agreement that applied to the waters between the Caribbean territories of the U.S. (Puerto Rico and USVI) and the BVI.
- **1980–Maritime Boundary Treaty:** the Venezuelan and U.S. governments ratified and entered into force the 1978 treaty that delimited the maritime boundaries between Puerto Rico/USVI and Venezuela (TIAS 9890).
- **1981–U.K. Proclamation Number 28:** the government of the U.K. extended the fishery limits of its Caribbean territory, Anguilla, to 200 NM.
- **1982–U.N. Convention on the Law of the Sea Treaty:** an international treaty developed by the U.N. but not yet ratified by the U.S. Most nations, including the U.S., adhere to its guidelines for maritime boundaries, including the territorial sea, contiguous zone, and exclusive economic zone (EEZ).
- **1983–Reciprocal Fisheries Agreement:** the 1979 Reciprocal Fisheries Agreement between the U.S. and U.K. was entered into force (TIAS 10545).
- **1983–Reagan Presidential Proclamation Number 5030 on the EEZ:** an EEZ was formally established to facilitate wise development and use of the oceans consistent with international law as well as to recognize the zone adjacent to a nation's territorial seas where a nation may assert certain sovereign rights over natural resources. Establishment of the U.S. EEZ advanced the development of ocean resources and promoted protection of the marine environment but did not affect other lawful uses of the zone, including navigation and overflight. This proclamation set the EEZ at 200 NM from

Table 6-1. Continued

the baselines of the U.S. and its territories, except where nations are less than 400 NM apart. In such cases, equidistant lines delineated the EEZ boundary. The EEZ boundaries coincided with those established by the 1976 FCMA. This presidential proclamation did not affect existing U.S. policies concerning the continental shelf, marine mammals, or fisheries. Jurisdiction and sovereign rights will be exercised in accordance with rules of international law.

- **1988–Reagan Presidential Proclamation Number 5928 on the Territorial Sea:** the seaward extent of the U.S. territorial sea was extended to 12 NM from the baseline of the nation and its territories by this proclamation. The territorial sea is the zone over which the U.S. exercises supreme sovereignty and jurisdiction from the airspace over the sea to the seabed and its soil. This extension of the territorial sea advanced national security and other interests of the U.S. This proclamation did not extend or alter existing federal or state laws (including jurisdiction, rights, legal interests, or obligations).
- **1993–Caribbean Maritime Boundary Delimitation Treaties:** two treaties were signed between the governments of the U.S. and the U.K. delineating the maritime boundaries between Puerto Rico/USVI and the BVI as well as between the USVI and Anguilla. Both boundary delimitations are based on equidistance, and both governments agreed not to claim or exercise sovereignty or jurisdiction over the waters, seabed, or subsoil of the other country. Both treaties listed points of latitude and longitude from which geodetic lines were drawn to form the boundaries between the territories of the U.S. and the U.K.
- **1994–U.N. Convention on the Law of the Sea:** the U.N. entered into force the 1982 Law of the Sea Treaty. It has yet to be ratified by the U.S.
- **1995–Caribbean Maritime Boundary Delimitation Treaties:** two maritime boundary treaties signed in 1993 by the governments of the U.S. and U.K. were ratified and entered into force.
- **1999–Clinton Presidential Proclamation Number 7219 on the Contiguous Zone:** the contiguous zone of the U.S. was established 24 NM from the nation's baseline by this proclamation. The contiguous zone is the area where the U.S. exercises the control necessary to prevent and punish infringement of its fiscal, customs, immigration, or sanitary laws and regulations within its territorial sea. Establishment of the U.S. contiguous zone advanced the law enforcement and public health interests of the nation. This proclamation did not change existing federal or state laws and did not alter the rights of the U.S. in the EEZ.

Sources: DoS (1977, 1986, 1994, 2000); Glassner (1995); Rosenberg (1998); de Blij and Muller (1999); DOALOS et al. (2001); IGIFL (2001); NARA (2001)

By the early 1980s, it was evident that the U.S. needed to control more than fisheries outside of its territorial waters. In 1983, President Reagan recognized the necessity of protecting, controlling, and developing the ocean area adjacent to the territorial waters of the U.S. by issuing Presidential Proclamation Number 5030. This proclamation established an EEZ 200 NM from the U.S. baseline and includes all areas adjoining the territorial waters of the U.S. and its territories except where another country lies closer than 400 NM from the U.S. The establishment of the EEZ gives the U.S. sovereign rights over the natural resources within the 200 NM zone, but this sovereignty does not affect the lawful use of this zone by other nations for navigation or overflight (DOALOS et al. 2001). Sovereign rights include the right to explore, exploit, conserve, and manage the natural resources of the U.S.

The U.N. Convention on the Law of the Sea Treaty (created 1982, entered into force 1994) delimits the international maritime sovereignties of coastal nations as 12 NM for territorial seas, 18 to 24 NM for a contiguous zone, and 200 NM for an EEZ (NARA 2001). Although the U.S. has not yet ratified the Law of the Sea Treaty, the U.S. considers much of the treaty to be customary law and thus abides by many of treaty's agreements. For instance, in 1988, U.S. Presidential Proclamation Number 5928 extended the seaward territorial limit of the U.S. to 12 NM from the U.S. baseline. This expansion of federal territorial waters from 3 NM (or in some cases 9 NM) to 12 NM provided the U.S. with jurisdiction and supreme

power over this area. The seabed and its resources, the biota found in the water column, and the airspace above the territorial seas, as well as the use of surface waters are all under the jurisdiction of the U.S. Although the territorial waters of the U.S. extend 12 NM seaward from its baseline, the part of the territorial sea closest to shore (3 to 9 NM) continues to be under the jurisdiction of each coastal state.

The governments of the U.S. and the U.K. signed two treaties related to Caribbean maritime boundaries in 1993 (both entered into force 1995; DoS 2000). The first treaty divided the marine jurisdiction between Puerto Rico/USVI and the BVI, creating a 288 NM long boundary between the territories of the two nations (DoS 1994). The second treaty established a 1.34 NM maritime boundary between the USVI island of St. Croix and the U.K. island of Anguilla (DoS 1994). This boundary line has the distinction of being one of the shortest in the world. Points of latitude and longitude (called turning or terminal points) defining the maritime boundaries are listed in both treaties. Boundary treaties delimiting the maritime boundary between Puerto Rico/USVI have yet to be negotiated with the Netherlands and the Dominican Republic. The boundaries established by the FMCA and EEZ proclamation remain in effect for the western Puerto Rican maritime boundary with the Dominican Republic and for a small portion of the southeastern boundary between the islands of the Netherlands and the USVI.

U.S. control over the waters adjacent to its shores was further solidified in 1999 when President Clinton's Presidential Proclamation Number 7219 extended U.S. federal jurisdiction by the additional 12 NM maximum allowed by international law. This 24 NM contiguous zone is measured from the U.S. baseline and, as its name implies, is an area contiguous or next to a nation's territorial waters that provides an added area of limited jurisdiction. The U.S. makes no territorial claims within its contiguous zone, but it does, however, claim the right to exercise the control necessary to prevent infringement of its fiscal, customs, immigration, or sanitary laws/regulations and to punish infringement of these laws/regulations committed within the zone (DOALOS et al. 2001). Additionally, the establishment of the U.S. contiguous zone advances both the law enforcement and public health interests of the nation. Table 6-2 summarizes the U.S. maritime boundaries and their associated jurisdictional implications.

Table 6-2. The maritime boundaries or zones of the U.S., its territories, and commonwealth nations as well as a description of the associated jurisdictional extent.

Maritime Boundary	Seaward Extent of Boundary	Jurisdictional Extent
State Waters	3 to 9 NM from U.S. baseline (depending on state's historical maritime boundary)	State jurisdiction of the air, sea, and seabed
Territorial Waters	12 NM from U.S. baseline	Full federal territorial jurisdiction of the air, sea, and seabed
Contiguous Zone	24 NM from U.S. baseline	Power to prevent and punish infringement of fiscal, customs, immigration, and sanitary laws or regulations
EEZ	200 NM from U.S. baseline	Sovereign rights over all natural resources and jurisdiction to protect marine environment

Source: DOALOS et al. (2001)

6.1.1 The Maritime Boundaries Relevant to the PROA/St. Croix OPAREA

While the vast majority of the PROA/St. Croix OPAREA is included within the limits of the U.S. EEZ, the northeastern grid blocks of the North PROA OPAREA (blocks 4, W-378, W-369, and W-429) and the northeastern most grid block (5) of the South PROA OPAREA are at least partially, if not entirely, outside of the U.S. EEZ boundary limit (Figure 6-1). The EEZ extends to 200 NM only north of Puerto Rico, while to the west, east, and south of Puerto Rico and the USVI, the EEZ boundary is constricted by the proximity of other nations and consists of median or equidistant lines between the U.S. territories and those other nations or territories.

In the PROA/St. Croix OPAREA, Puerto Rico claims jurisdiction over 3 marine leagues (approximately 9 NM) seaward from its baseline, while the USVI of St. Thomas, St. Croix, and St. John maintain jurisdiction over the first 3 NM seaward from their respective baselines. The territorial waters and contiguous zone extend 12 and 24 NM where possible around Puerto Rico and the USVI. The BVI and Anguilla, however, claim 3 NM from their baselines as their territorial seas (DoS 1994).

6.1.2 U.S. Maritime Boundary Effects on Federal Legislation and Executive Orders

According to the presidential proclamations and treaties that extended or established the maritime boundaries of the U.S. (territorial seas, contiguous zone, and EEZ), existing federal or state laws or any associated jurisdiction, rights, legal interests, or obligations were not extended or altered in any way. The maritime boundary associations detailed in the legislation or orders relevant to the PROA/St. Croix OPAREA are listed below (see Chapter 1 for a full description of the legislation and their applications). High seas generally refer to international waters outside the jurisdiction of any single nation.

- The Marine Mammal Protection Act (MMPA) protects, conserves, and manages marine mammals in waters under the jurisdiction of the U.S., which are defined by the MMPA as the U.S. territorial seas, EEZ, and the eastern special areas between the U.S. and Russia. The act further regulates “takes” of marine mammals on the global commons (i.e., the high seas or Antarctica) by vessels or persons under U.S. jurisdiction.

- The Endangered Species Act (ESA) regulates the protection, conservation, or management of endangered species in the U.S. territorial land and seas as well as on the high seas.

- The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), also known as the Sustainable Fisheries Act (SFA), claims sovereign rights over fish and fishery management in the U.S. EEZ (except for highly migratory species). The U.S. cooperates with nations or international organizations involved in fisheries for the highly migratory species in order to conserve and promote optimum yields of the species in their entire range in and beyond the U.S. EEZ.

- The National Environmental Policy Act (NEPA) establishes a Council on Environmental Quality and a national policy that will encourage productive harmony between humans and their environment and prevents or eliminates damage to the environment; boundaries include the territorial lands and waters of the United States to the limit of the territorial seas.

- The Marine Protection, Research, and Sanctuaries Act (MPRSA) regulates the dumping of materials in the ocean. It is applicable to material transported by any U.S. person, vessel, aircraft, or agency from any location in the world and by any person outside the U.S. intending to dump materials in U.S. territorial seas and the contiguous zone.

- Executive Order 12114 extends environmental impact evaluation requirements beyond the territorial seas and contiguous zone of the U.S. to include the environment of other nations and the global commons outside the jurisdiction of any nation.

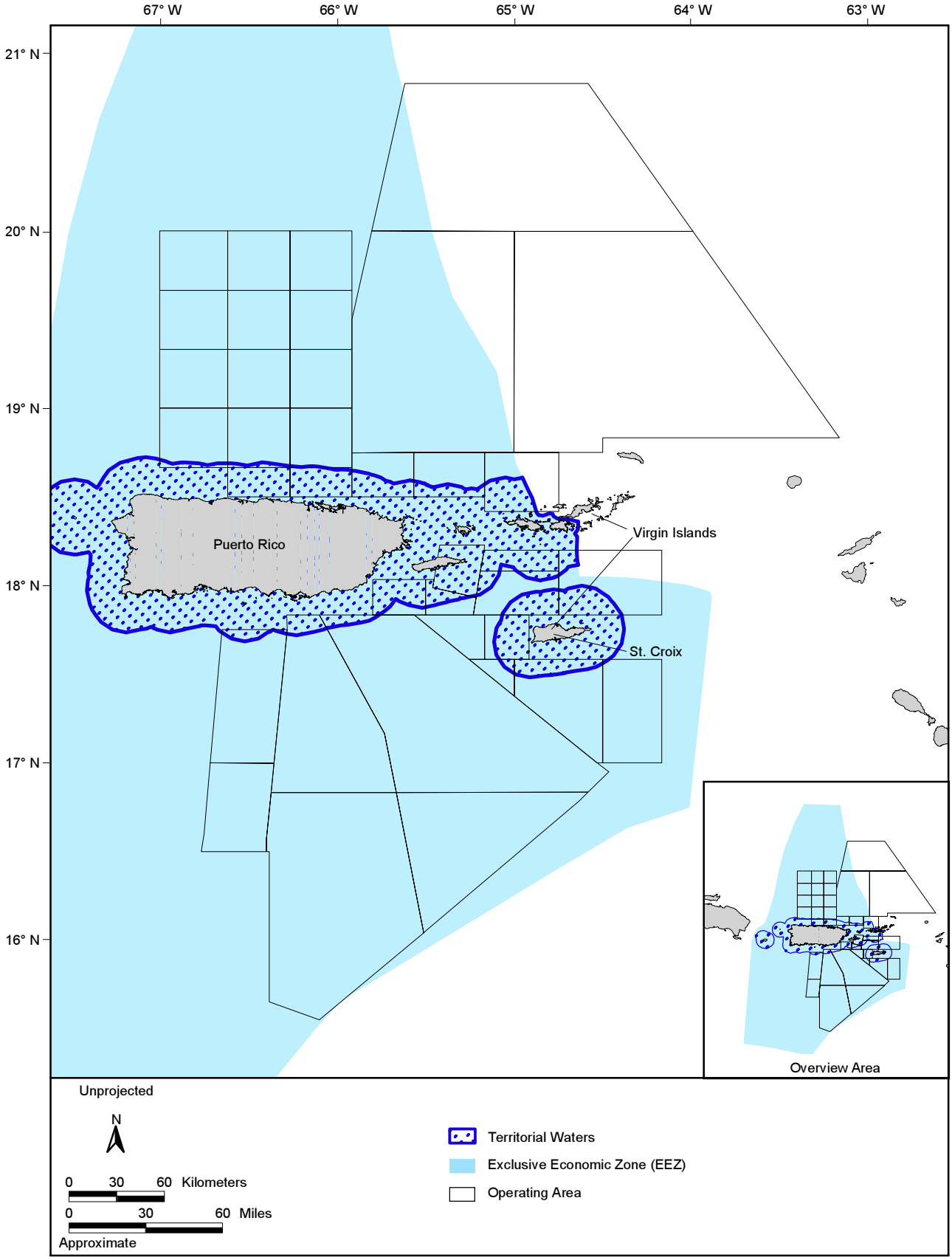

Figure 6-1. The exclusive economic zone (EEZ) and territorial waters of Puerto Rico and the U.S. Virgin Islands. Source data: DoD (2001). Source map (scanned): CFMC (2002).

- The Marine Plastic Pollution Research and Control Act (MPPRCA) prevents pollution of the marine environment by any vessel with U.S. registry or under U.S. authority and all vessels in the U.S. territorial waters or EEZ.

6.2 NAVIGABLE WATERWAYS

Navigable waterways of the U.S. are those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. A determination of navigation, once made, applies laterally over the entire surface of the water body and is not extinguished by later actions or events that impede or destroy navigable capacity (33 CFR Part 329). Shipping lanes usually refer to the traffic lanes ships use when close to port or land. Although there is good deal of confusion about the terms navigable waterways and shipping lanes, we use them hereafter synonymously.

The Caribbean Sea and northwestern Atlantic Ocean support a high volume of ship traffic heading to and from ports via the Panama Canal as well as traffic traveling north and south to various ports along the North American seaboard. Commercial (domestic and international) shipping comprises a large portion of this traffic. The Mona and Anegada Passages serve as key entryways into the Caribbean Sea with ship traffic ultimately destined for the Panama Canal or ports along the northern coast of South America. The PROA/St. Croix OPAREA is in the direct path of commercial shipping lanes between the eastern U.S. seaboard and the Panama Canal (Figure 6-2). Major ports lie within the OPAREA boundaries. San Juan, on the northeastern Puerto Rico shore, is the largest natural harbor in the Caribbean while St. Thomas' port of Charlotte Amalie, found on the south-central coast, is one of the Caribbean's best natural deepwater harbors (CIA 2001).

Most of the shipping lanes in the PROA/St. Croix OPAREA converge in the vicinity of the San Juan port, which is the major trans-shipment point for the eastern Caribbean (Verizon Information Services–Puerto Rico, Inc. 2001). A domestic shipping lane originates in San Juan and circumnavigates around the Puerto Rican coastline with lanes branching to the other Puerto Rican port municipalities. Another domestic shipping lane circumvents the Virgin Passage and continues to the islands of St. Thomas and St. Croix. It is likely that commercial shipping traffic will be encountered on the Atlantic Ocean side of the OPAREA but much less likely on the Caribbean Sea side of the OPAREA.

6.3 MARINE PROTECTED AREAS

Marine protected areas (MPAs), as defined in Executive Order 13158, are "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." Section 5 of Executive Order 13158 stipulates, "each Federal agency whose actions affect the natural or cultural resources that are protected by an MPA shall identify such actions. To the extent permitted by law and to the maximum extent practicable, each Federal agency, in taking such actions, shall avoid harm to the natural and cultural resources that are protected by an MPA." Executive Order 13158 also calls for the preparation of annual reports by federal agencies describing the actions they have taken over the previous year to implement the order.

MPAs are a collection of marine resource spaces that conserve and protect biological integrity, habitat diversity, as well as the social or cultural value of a specific portion of the marine environment (NRC 2000). MPAs are considered an effective conservation tool for sustaining ocean ecosystems (Agardy 1999; NRC 2000). Many areas of the U.S. marine waters receive some level of management protection. These marine-managed areas have to meet certain criteria to be designated as an MPA. There are currently 251 federal sites that are designated as MPAs. These federal sites include national marine sanctuaries, national seashores, national parks, national monuments, federal fisheries management zones, federal threatened/endangered critical habitat, federal threatened/endangered species protected areas, national wildlife refuges, national estuarine research reserves, and ecological preserves (NOAA 2002a). A good summary of the legislation regarding MPA designation may be found in Zinn and Buck's

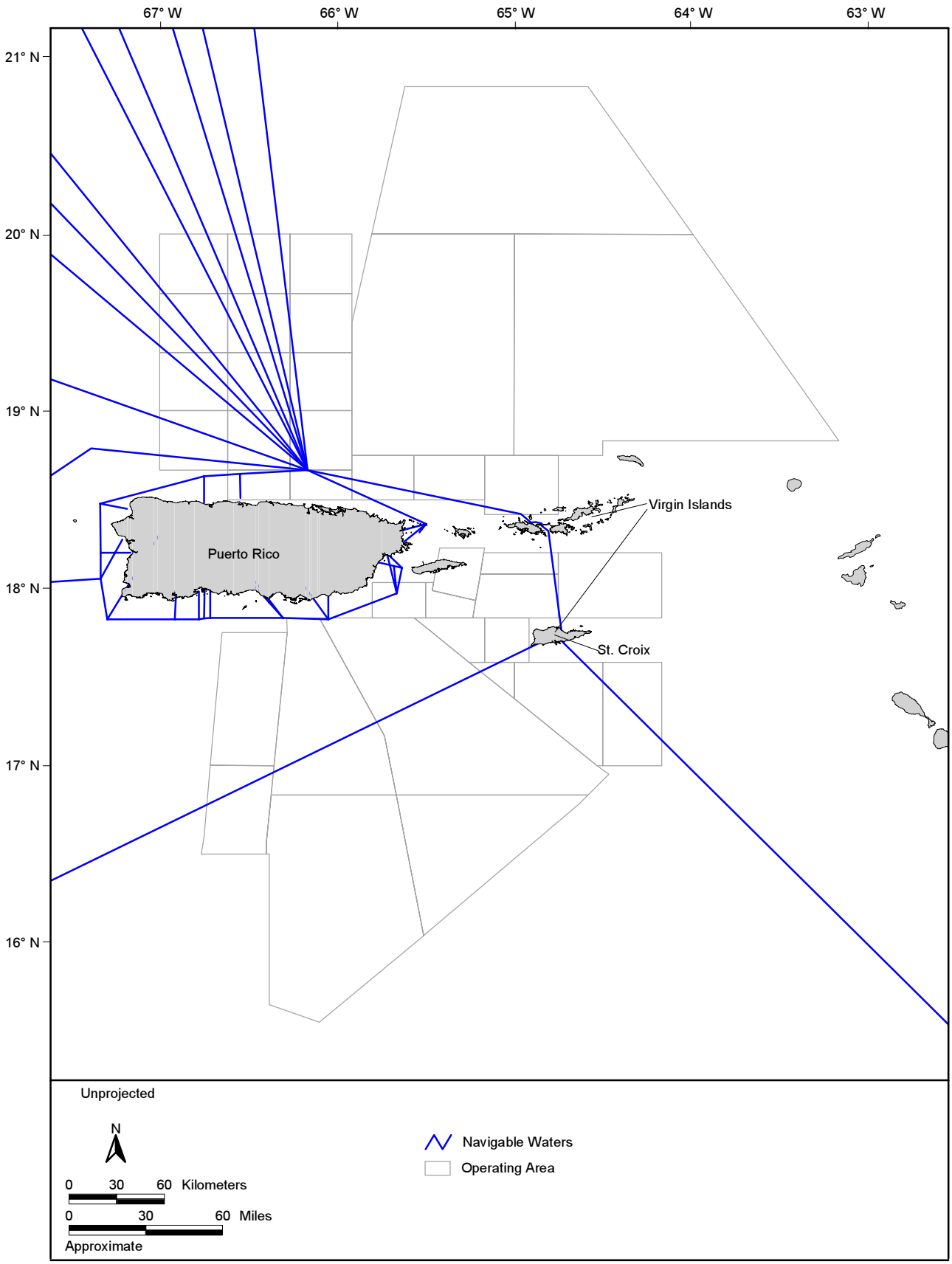

Figure 6-2. Navigable waters in the PROA/St. Croix OPAREA and vicinity. Map adapted from: DoT (2000).

(2001) review, while the official federal website (http://mpa.gov) provides more information on U.S. MPAs, including the criteria used for site designation.

MPAs are found throughout the wider Caribbean region with the governments of the U.S. and U.K. having established 17 MPAs in the northeastern Caribbean Sea. There are 11 established MPAs under U.S. jurisdiction and six MPAs under the jurisdiction of the U.K. within the PROA/St. Croix OPAREA (Figure 6-3). MPAs under U.S. jurisdiction include critical/protected habitats, national wildlife refuges, ecological/historical reserves, national estuarine research reserves, national marine sanctuaries, national parks, national monuments, and national seashores. British MPAs are largely designated as marine parks but include a variety of marine resource areas. National marine sanctuaries and national seashores are the only types of MPAs not found in the PROA/St. Croix OPAREA.

6.3.1 National Marine Sanctuaries

There are currently 12 designated national marine sanctuaries in U.S. waters and one proposed site in the Great Lakes, creating a system that protects over 36,260 km^2 (14,000 statute mi^2) of ocean habitat. No national marine sanctuaries have been designated in the vicinity of the PROA/St. Croix OPAREA.

6.3.2 National Seashores

Although the National Park Service protects and manages 10 national seashores in the U.S., no national seashores are located in the northeastern Caribbean Sea.

6.3.3 National Parks and Monuments

The National Park System of the U.S. is composed of 384 areas covering more than 83 million acres in 49 states, the District of Columbia, American Samoa, Guam, Puerto Rico, Saipan, and the USVI (NPS 2000). National parks are generally large natural places having a wide variety of attributes, including significant historic assets (NPS 2000). The Antiquities Act of 1906 authorizes the President of the U.S. to publicly proclaim a landmark, structure, or other object of historic or scientific interest as a national monument if it is situated on lands owned or controlled by the federal government (NPS 2000). There are two national parks or monuments in the PROA/St. Croix OPAREA.

The Virgin Islands National Park covers approximately three-fifths of St. John and nearly all of Hassel Island surrounding the Charlotte Amalie harbor on St. Thomas (NPS 2002). Sea turtles occasionally nest in the protected areas of Trunk Bay, Hawksnest Bay, and Cinnamon Bay where coral reefs flourish and tropical forests fringe the shore. Relics from pre-Colombian Amer-Indian civilizations, Danish colonial sugar plantations, and African slave and post-emancipation subsistence cultures are found within the park.

Buck Island Reef is the only national monument in the Caribbean area under U.S. jurisdiction. This barrier reef, consisting primarily of elkhorn coral, surrounds two-thirds of St. Croix Island in the USVI and is located near Christiansted (NPS 2001a). The island is a rookery for the regionally endangered brown pelican as well as a nesting area for three species of sea turtles, including the hawksbill sea turtle.

6.3.4 Critical Habitat/Protected Habitats

The NMFS responsibilities include rebuilding and maintaining sustainable fisheries, promoting the recovery of protected species, and protecting and maintaining the health of coastal marine habitats. To satisfy these responsibilities, the NMFS uses protected areas as one of several tools to conserve and manage marine resources. The NMFS MPA sites fall under three major categories: fisheries management zones, threatened/endangered species critical habitat areas, and threatened/endangered species protected areas (no protected areas or critical habitat areas listed as MPAs exist in the vicinity of the PROA/St. Croix OPAREA).

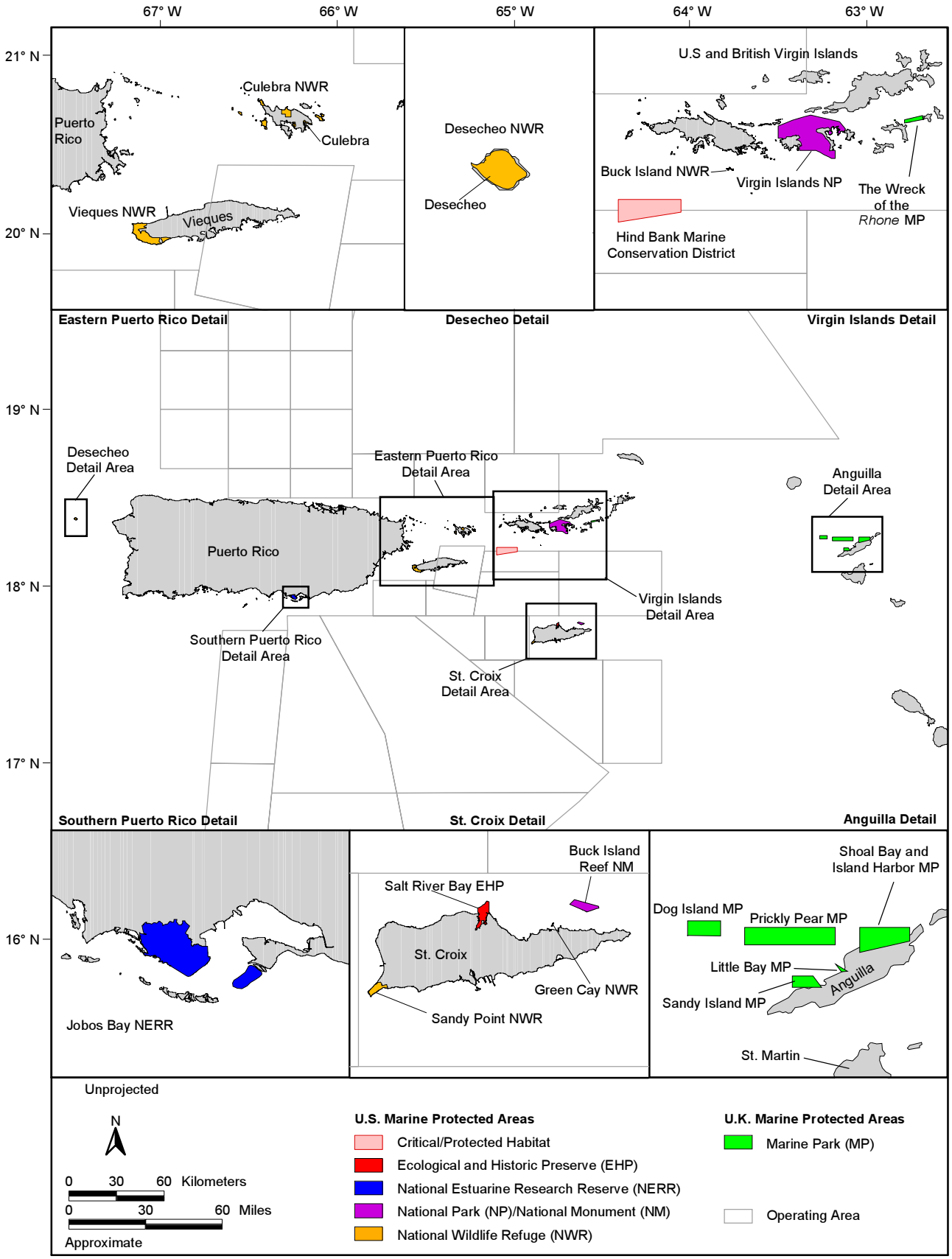

Figure 6-3. Marine protected areas (MPAs) in the PROA/St. Croix OPAREA and vicinity. Source data: NOS (2001a), NPS (2001c), ADFMR (2002), BVI NPT (2002), NOAA (2002c), and NWRS (2002). Source map (scanned): Tamarindo Estates (2001).

Fishery management zones (FZ) are areas that are closed, at least partially, to fishing activity. The NMFS has the jurisdiction to restrict or even prohibit the use of one or more fishing gear types in some areas in order to protect habitats, fishery stocks, or species assemblages and/or to promote the recovery of threatened or endangered species, such as marine mammals, sea turtles, or fishes. Most of these area closures are temporary; however, in some locations, they might be year-round for one or more years. For a fishing area closure to be considered an MPA, it must prohibit one or more fishing activities year-round and the closure must be intended to be permanent (NOAA 2002b). The Hind Bank Marine Conservation District is the only FZ found in the PROA/St. Croix OPAREA. It is located southwest of St. Thomas and is closed year-round. Within this 16 NM^2 designated marine conservation area, fishing and anchoring of fishing vessels is prohibited (NMFS 1999). The area is closed year-round to fishing to protect red hind spawning aggregations.

The ESA allows the designation of geographic areas as critical habitat for threatened or endangered species. Both the physical or biological features essential to the conservation of a threatened or endangered species are included in the habitat designation. Designation of critical habitat affects only federal agency actions and federally funded or permitted activities. There are critical habitats designated for the green, hawksbill, and leatherback sea turtles on the islands of Mona, Culebra, and St. Croix (see Section 3.2 for more information). The U.S. federal government, however, currently does not classify these particular critical habitats as MPAs (Brownlee personal communication).

6.3.5 National Wildlife Refuges

Although the National Wildlife Refuge System contains all types of habitat, with 538 established national wildlife refuges (NWR), the system protects more marine habitat area than any other federal agency. Approximately 140 to 150 refuges nation-wide contain marine and estuarine habitat. These MPAs provide habitat for endangered species such as the West Indian manatee and sea turtles in addition to countless shorebirds. The refuge system contains about 2.6 million acres of coral reefs and adjacent ocean habitat. Thirteen NWRs found along U.S. coasts contain significant coral habitat (RefugeNET 2002).

Seven NWRs located in the Caribbean Sea are considered MPAs (Brownlee personal communication). Six of the seven occur within the PROA/St. Croix OPAREA or in its vicinity: Sandy Point NWR, Vieques NWR, Green Cay NWR, Culebra NWR, Buck Island NWR, and Desecheo NWR. While both Cabo Rojo NWR and Laguna Cartegna NWR are located on the island of Puerto Rico, the boundaries of neither extend to the ocean shoreline and, therefore, are not classified as MPAs (Vandegraft personal communication). Buck Island NWR, although similarly named as the Buck Island Reef National Monument, is not located on the same island vicinity.

The Culebra NWR is comprised of about 1,480 acres, with four tracts found on the main island of Culebra, while 23 islands and rock outcrops off shore are also included in the refuge (Tamarindo Estates 2001). The refuge is well known as a nesting site for a variety of seabirds; it additionally preserves important habitat for endangered sea turtles and the Culebra giant anole lizard. The beaches of Culebra are included as critical habitat for the endangered hawksbill sea turtle. Green, leatherback, and loggerhead sea turtles also have been observed there. Extensive coral reef systems and seagrass flats at Culebra are critical as development and foraging habitat for these turtles.

6.3.6 National Estuarine Research Reserves

National estuarine research reserves (NERR) encompass relatively pristine estuarine areas that contain key habitat and are protected from significant ecological change or developmental impacts. The reserves also provide reference sites for research, monitoring, and education programs that focus on functional ecosystems. NERRs include a variety of rare, endangered, or threatened species. There is one NERR located in the PROA/St. Croix OPAREA; Jobos Bay NERR is the second largest estuarine area in Puerto Rico (NOS 2001b). It is home to the endangered peregrine falcon, hawksbill sea turtle, West Indian manatee, and brown pelican. It is commercially important for marine recreation, commercial and recreational fishing, as well as ecotourism.

6.3.7 Ecological/Historical Preserves

The Salt River Bay National Historic Park and Ecological Preserve is the only ecological preserve found in the PROA/St. Croix OPAREA. Ecological preserves are managed by the NPS. This preserve is located on the north-central coast of St. Croix. It not only contains one of the largest remaining mangrove forests in the USVI but also has historical importance (Legal Information Institute 2002; NPS 2001b). It is the only known site where members of Christopher Columbus' expedition set foot on what is now U.S. territory. It also contains the only pre-Columbus ceremonial ball court ever discovered in the Lesser Antilles as well as village middens and burial grounds.

6.3.8 Marine Parks of the Caribbean United Kingdom

The BVI National Parks Trust (NPT) was established in 1961 by the government of the BVI. It is a quasi-governmental organization whose responsibility it is to manage, preserve, and promote areas that have been designated as national parks by the U.K. (Fleming 2001). The NPT has authority under the National Parks Ordinance, which allows laws to be decreed that regulate access to and use of the parks (Fleming 2001). The BVI NPT currently manages 19 national parks, including one established marine park, Wreck of the *Rhone* National Park, and three proposed marine parks (The Baths National Park, Spring Bay National Park, and West Dog Island National Park) (Woodfield personal communication). The Wreck of the *Rhone* marine park off Tortola has always been the most popular dive site in the BVI. Underwater artifacts that are excavated must now remain underwater in the park (Handler 2001). The Wreck of the *Rhone* is one of the smallest marine parks in the world (Mascia 2000).

In 1989, the government of Anguilla proposed a comprehensive marine parks program. The Anguilla National Trust was established in 1993 and acts as custodian of Anguilla's heritage, preserving and promoting the island's natural environment and its archaeological, historical, and cultural resources for present and future generations (Anguilla National Trust 2001). The Anguilla National Trust is a governmental organization that manages the park and acts as an umbrella for all of the local non-governmental and non-profit organizations on the island. Five parks are currently established: Shoal Bay, Sandy Island, Prickly Pear Cay (including Seal Island), Dog Island, and Little Bay (CEP 1996) (Figure 6-3).

6.4 SCUBA DIVING SITES

Scuba diving and snorkeling are popular recreational activities throughout the Caribbean region, including the island areas within and adjacent to the PROA/St. Croix OPAREA. In fact, some of the most popular scuba destinations for dive travelers are along the shores of Puerto Rico, the USVI, and the BVI. Divers are attracted to the warm air and water temperatures found throughout the year, the clear underwater visibility, and the interesting coral reef and shipwreck dive sites. The vast majority of dive sites off Puerto Rico and the Virgin Island, however, do not fall within the boundaries of the PROA/St. Croix OPAREA.

The Virgin Islands collectively include approximately 90 islands, islets, and cays (Handler 2001). Most diving is done close to shore in less than 27 m of water. Despite this, diving is done primarily from boats rather than from shore, with few exceptions (Handler 2001). This is mostly due to the lack of adequate shore access points. The BVI attract about 300,000 visitors a year, many of whom participate in diving and sailing. There are 63 named dive sites in the BVI that are particularly popular with divers (Handler 2001) (Figure 6-4). There are many diving and snorkeling sites around the three main islands of St. John, St. Thomas, and St. Croix in the USVI. Much of St. John is comprised of the Virgin Islands National Park and offers numerous dive sites close to shore. The waters around St. Thomas include 43 popular dive sites, mostly located off the eastern and southern coasts of the island (St. Thomas Scuba Diving Guide 2001). The vast majority of the more than 30 primary dive sites off St. Croix are along the north coast, close to shore. There are several shipwrecks as well as several sites featuring unusual anthropogenic substrates, such as a dump truck (Buckley personal communication).

Historically, Puerto Rico has not shared the same popularity among divers as some of the better-known dive destinations in the Caribbean. In recent years, however, this situation has changed (Simonsen

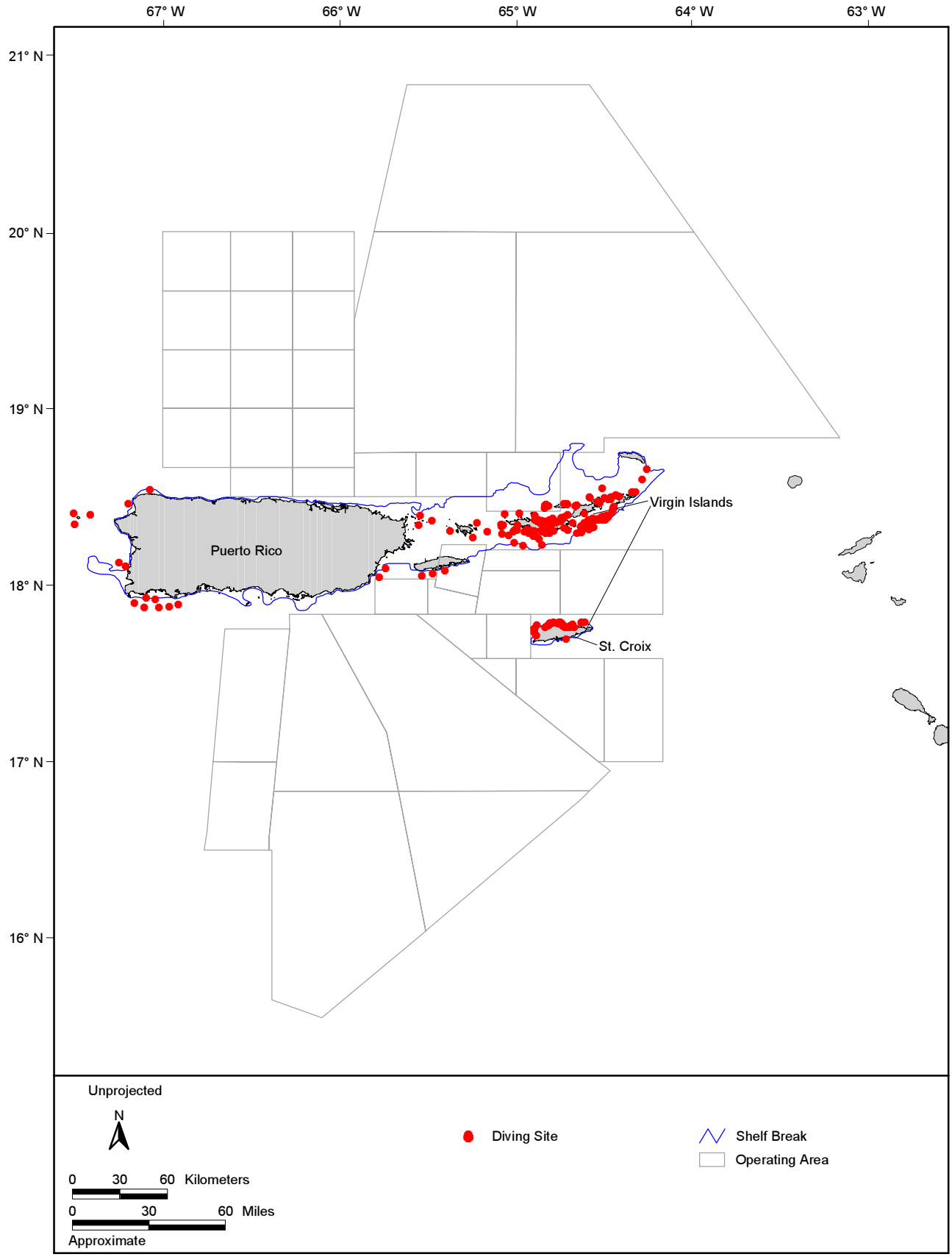

Figure 6-4. Recreational diving sites in the PROA/St. Croix OPAREA and vicinity. Source data: NOS (2001a) and Buckley (2002). Source information: Simonsen (2000), Handler (2001), and St. Thomas Scuba Diving Guide (2002).

2000). As more dive sites become identified and the diving infrastructure on Puerto Rico becomes better developed, more divers are visiting Puerto Rico. Currently, 54 dive sites are visited with regularity (Figure 6-4). Visibility close to the main island is so poor that most diving is done around the smaller offshore islands (Culebra, Vieques, and Desecheo) or is limited to the southwest coast of the main island. The southwest coast offers excellent diving along La Parguera wall and among the reefs near Cabo Rojo (Simonsen 2000). The presence of three bioluminescent bays makes diving in Puerto Rican waters an unusual experience, as these bioluminescent waters are rare elsewhere in the Caribbean. Most dive operations in Puerto Rico are still small scale and informal but are slowly evolving to provide services comparable to other dive-oriented islands.

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7.0 RECOMMENDATIONS

This marine resource assessment (MRA) is an inventory and description of the marine resources, including protected marine species and habitats, occurring in the PROA/St. Croix OPAREA. Caribbean marine ecosystems have been studied by a relatively small number of individuals or organizations. Many data gaps, therefore, became evident while preparing this MRA. Additional information on the natural history of marine mammals and sea turtles is needed, as well as more recent oceanographic data. It is clear that the acquisition and compilation of additional data will enhance the Navy's planning process. An improved understanding of the spatial and temporal occurrences of protected or managed marine species will lead to a reduction in impacts or conflicts in usage of the OPAREA by both marine organisms and the Navy. Information in this MRA also serves as the groundwork for potential future environmental documentation and ensures compliance with federal laws and statutes.

The recommendations provided in this chapter are important to advancing the Navy's knowledge of marine resources in the area and have been prioritized to assist Navy planners. Recommendations with a rating of 1 are considered the highest priority, while those with a rating of 3 are considered the lowest priority. The assignment of a priority value is based on the usefulness of the recommendation for environmental documentation and deconflicting the usage of the OPAREA. The priority designations are relative to one another and have no reflection on a recommendation's merit. Recommendations are roughly ordered by priority value. None of the recommendations were subjected to a financial analysis but each is assigned a relative cost designation. The relative cost of each recommendation is labeled low, moderate, or high. Low-cost recommendations may be completed at a cost of several hundred to a few thousand dollars while moderate-cost projects could range in cost from thousands to tens of thousands of dollars. High-cost research initiatives may range from tens of thousands to over one hundred thousand dollars. There is no correlation between price and priority.

The recommendations are grouped into two general categories: "Marine Resource Assessments" (related to the production or evaluation of the MRA) and "Environmental Documentation" (needed to improve planning and mitigation strategies).

7.1 MARINE RESOURCE ASSESSMENTS

- Update the MRA every two to four years. A full revision of the text, data, GIS maps, and other informational components of the MRA will be needed so that newly available datasets and published literature can be incorporated. The best (i.e., most recent, most complete, and most accurate) available information is needed by the Navy to evaluate future actions and consider adjustments to training exercises or operations in order to mitigate any potential impacts to protected marine resources. Periodic updates will be of moderate cost relative to the initial MRA. Cost: Medium. Priority: 1.

- Obtain marine mammal and sea turtle datasets for the PROA/St. Croix OPAREA that were not available for this MRA (see Appendix A, Appendix A-2 for all known sources of marine mammal and sea turtle data while those included in this MRA are found in Appendix A, Table A-2.) In some cases, datasets may have to be purchased from researchers or funding provided to assist researchers with data compilation and quality control procedures. Other datasets may need to be converted into an electronic format. Datasets that have not been incorporated in this MRA include:

  - Cetacean sightings collected from 1969 and 1974 by the late Dr. Howard Winn, University of Rhode Island (URI). These data are handwritten and would require an extensive amount of effort to organize and convert the information into a usable format (contact: Dr. Robert Kenney, URI).
  - NMFS-SEFSC bottlenose dolphin survey conducted off the U.S. Virgin Islands (contact: Dr. Gerald Scott, NMFS-SEFSC).
  - USVI opportunistic cetacean sightings (contact: Ms. Barbara Kojis, Department of Planning and Natural Resources, USVI).
  - Fishery bycatch (in particular, longline bycatch of marine mammals and sea turtles) (contact: Dr. Gerald Scott, NMFS-SEFSC).

- Puerto Rico manatee tagging survey (contact: Dr. James Reid, USGS).
- Post-1995 sea turtle strandings (contact: Secretary, Puerto Rico Department of Natural and Environmental Resources).
- Satellite-tagging survey of leatherback sea turtles nesting on Culebra and near Fajardo, Puerto Rico (contact: Dr. Molly Lutcavage, New England Aquarium).

Acquisition and analysis of existing data will be less expensive than funding survey efforts (particularly for marine mammals and sea turtles). Cost: Low. Priority: 1.

- Peer-review the MRA. To increase the utility of the MRA, regulatory agencies (e.g., NMFS, USFWS, state agencies), the scientific community, and potential governmental users (e.g., Marine Corps, Air Force, U.S. Coast Guard) should review this document. Biologists from universities and agencies (Table 7-1) could evaluate the collection, synthesis, and interpretation of data (including data completeness) and provide suggestions for improvements to the MRA. Cost: Low. Priority: 2.

Table 7-1. Suggested expert reviewers of the PROA/St. Croix OPAREA marine resource assessment.

Name	Affiliation
Dr. Richard S. Appeldoorn	University of Puerto Rico
Dr. Peter August	University of Rhode Island, Coastal Institute
Dr. Karen Bjorndal	University of Florida
Dr. Philip Clapham	National Marine Fisheries Service–Northeast Fisheries Science Center
Dr. Karen Eckert	Wider Caribbean Sea Turtle Conservation Network (WIDECAST)
Dr. Robert Hofman (retired)	Marine Mammal Commission, Scientific Program Director
Dr. James Mead	Smithsonian Institution
Dr. Anne Meylan	Florida Marine Research Institute
Dr. Keith Mullin	National Marine Fisheries Service–Southeast Fisheries Science Center
Dr. Gerald Scott	National Marine Fisheries Service–Southeast Fisheries Science Center
Mr. James Reid	Sirenia Project, U.S. Geological Survey
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7.2 ENVIRONMENTAL DOCUMENTATION

- Develop a program to train observers assigned to Navy ships. Given the increasing interest in marine resource protection in the U.S., such training should be included in the basic training of all at-sea sailors, as well as all officer candidates (e.g., Naval Academy, Officer Candidate School). Observers

would be trained to identify marine mammal and sea turtle species at sea, collect and interpret basic hydrographic data, and properly record data. Standardized data collection methods and forms, as well as a centralized database for storage and analysis of the information, would be required to make this program viable. The cost of training observers is relatively modest, especially considering the cost of surveys (i.e., dedicated ship surveys). The potential for the acquisition of large amounts of quality data is a major benefit of this program. Cost: Medium. Priority: 1.

- Utilize Navy ships as platforms-of-opportunity for the collection of marine mammal and sea turtle sighting data. Scientific survey vessels are few in number and their deployments may not correspond to regions of historically low survey effort within the OPAREA (Figure 7-1). Experienced marine animal observers onboard Navy ships within the OPAREA can greatly add to our knowledge of the diversity and distribution of marine mammals and sea turtles in the Caribbean. Observers could be trained Navy personnel. Alternatively, experienced civilians could be used and Navy personnel would not need to be responsible for both their duties and marine mammal/sea turtle observations. This would be a relatively inexpensive program, the cost of which would primarily be the training and salaries of observers. The quantity and quality of data collected will be a function of the number of observer deployments, as well as the specific cruise tracks of the ships. Cost: Low. Priority: 1.

  - Navy ships could also be used as platforms-of-opportunity for oceanographic measurements. Flow-through systems, which automatically measure such parameters as chlorophyll, water temperature, and salinity are moderately expensive initially (i.e., purchase and installation), but incur no labor costs during deployment. Data would be downloaded once the ship returns to port. Cost: Low to Medium. Priority: 1.

- Deploy flipper, pit, or satellite tags on sea turtles to better understand the behavioral ecology of nesting sea turtles, including their inter-nesting movements, habitat use, site fidelity, dive behavior, and nesting frequency. Sea turtles move through the PROA/St. Croix OPAREA and nest on beaches contiguous to the OPAREA. Due to Vieques Island's proximity to Culebra and St. Croix, research efforts on Vieques should mirror those being conducted at Culebra and St. Croix, as preliminary data indicate that individual transient females may utilize nesting beaches on all three islands during a single season. Improved monitoring of nesting beaches and frequent censusing of sea turtle nests is needed to better estimate the actual number of sea turtles utilizing Vieques Island each year. Cost: Medium. Priority: 1.

- Review each record of Dr. Antonio Mignucci-Giannoni's marine mammal sighting dataset to verify species identifications. A confirmed species identification requires at least one of the following: (a) photos or video showing diagnostic features, (b) voucher specimens, such as the skull, (c) detailed description of diagnostic characters, or (d) identification by an experienced and knowledgeable observer. This type of information is not readily available for most of the records in the dataset, and there are records for reputed occurrences of sei whales and common dolphins in the PROA/St. Croix OPAREA that are considered suspect. Confirming the species identifications will provide a clearer picture of the species diversity and occurrence patterns of marine mammals in the PROA/St. Croix OPAREA. Cost: Low to Medium. Priority: 1.

- Conduct aerial and shipboard marine mammal surveys and aerial sea turtle surveys in seasons and in grid blocks of the PROA/St. Croix OPAREA that have been relatively neglected by previous efforts. Compared to many sections of the coastal U.S., the Caribbean Sea has been poorly surveyed. Aerial surveys are essentially non-existent except in Puerto Rico and only a few shipboard surveys for marine mammals have been conducted (Figure 7-1). Regions with little to no survey effort comprise more than 50% of the OPAREA. By focusing attention on these areas, further insight into the occurrence of marine mammals and sea turtles may emerge. Understanding the spatial and temporal occurrence of protected species within the OPAREA will allow Navy planners to schedule operations in such a way as to avoid or minimize potential impacts. There is a tremendous amount of public interest in marine mammals and sea turtles, as well as extensive protective legislation. Given the high-profile status of these species, it would be beneficial to learn as much as possible about them, especially their distribution. The following specific types of surveys are recommended:

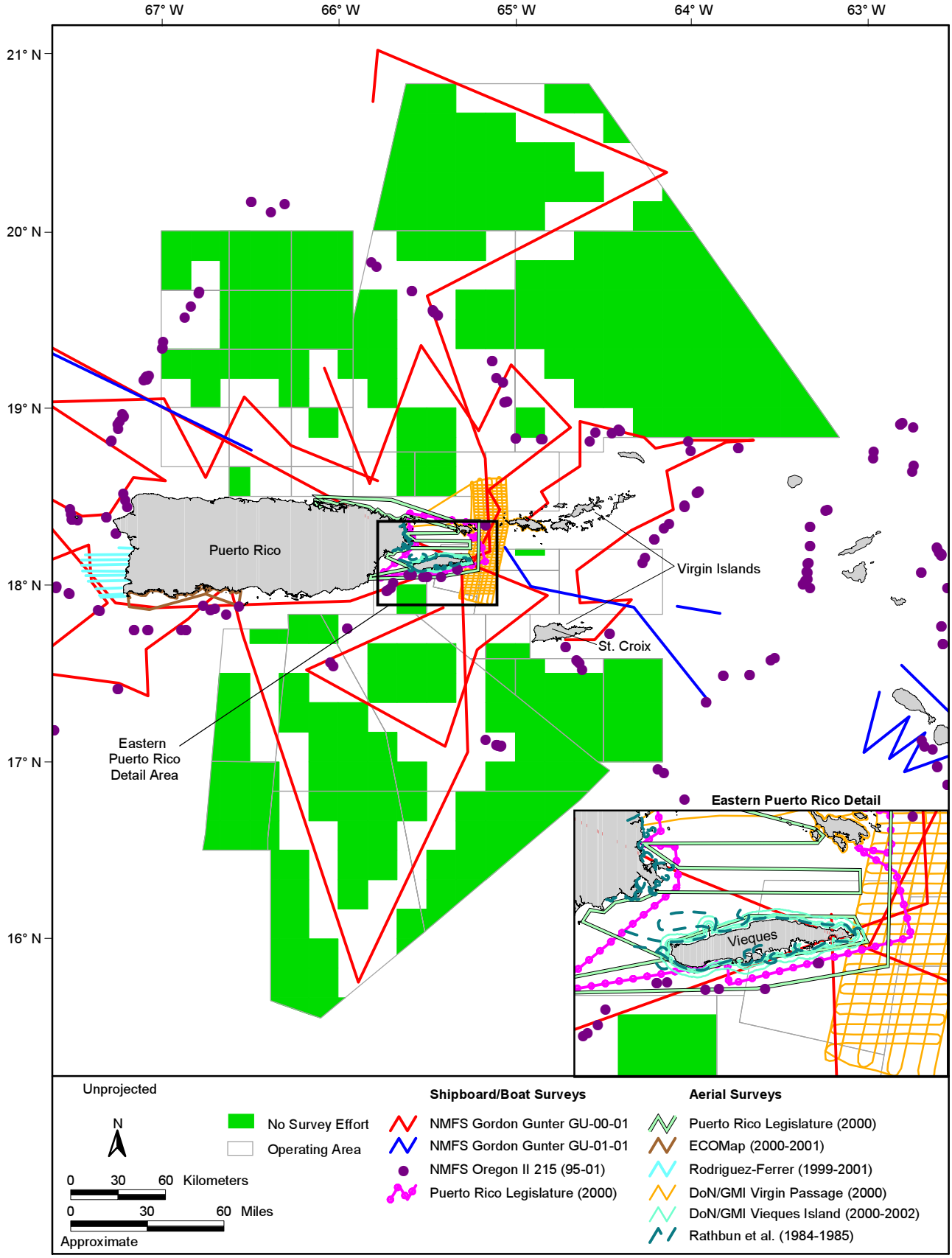

Figure 7-1. Tracklines and transect coordinates of shipboard and aerial surveys in the PROA/St. Croix OPAREA and vicinity as well as areas of no survey effort. Source data: NMFS-SEFSC. Source maps (scanned): Rathbun et al. (1985), Mignucci et al. (2000, 2002), Swartz and Burks (2000), Rodríguez-Ferrer (2001), and Swartz et al. (2002).

- Conduct shipboard sighting and acoustic surveys in all OPAREA grid blocks during all seasons (Figure 7-1). Effort is especially critical in grid blocks farthest from Puerto Rico, the U.S. Virgin Islands, and the British Virgin Islands, since there is not much data on the occurrence of cetaceans and sea turtles offshore of these islands. Survey tracklines for recent NMFS surveys for humpback whales in this area were reduced in length to accommodate active Navy exercises in many of the areas to the north and south of Puerto Rico. The NMFS recommended that the number of survey tracklines be increased to cover the areas from nearshore to the 5,000 m isobath around Puerto Rico to obtain an increased cetacean encounter rate sufficient to achieve the desired statistical precision to estimate abundance.

  Acoustic surveys should continue to be conducted in conjunction with sighting surveys. These surveys are particularly useful for vocal species, such as humpback whales and sperm whales. Sperm whales are deep divers, spend little time at the water's surface, and are therefore often missed during visual sighting surveys.

  The benefit of surveys dedicated to cetaceans is that areas with depauperate sighting data can be targeted (Figure 7-1). Aerial surveys flown at the same time a ship survey is underway may provide additional estimates of group sizes and expand the range of the vessel survey and verify both acoustic and visual detections of whales. Cost: High. Priority: 2.

- Conduct aerial sighting surveys in the grid blocks within a feasible distance from a staging area during all seasons. It should be noted that the majority of grid blocks lie beyond the range of standard aircraft used for surveys (Figure 7-1). Grid blocks that could be covered by aerial surveys include 2A, 2B, 3A, 3B, 4, 6B, UTR (6A), W-428, 8, 7, UTR (11), 10, 12, and the southern most part of W-369. Aerial sighting surveys should be conducted above the Puerto Rico Platform, along its shelf break, and offshore of the platform in order to better understand the platform's role in the distribution of cetaceans and sea turtles.

  For this area, the advantages of using aerial surveys over boat or ship-based surveys is that aircraft can be used to cover a larger area more quickly, are able to survey regions such as coral reef and shoal areas that are common in the Caribbean but are shallow and hazardous to boats, are able to wait out poor weather periods at a lower cost, and can more effectively exploit narrow fair-weather windows that are typical in the Caribbean region. Results of aerial surveys could be used to delineate areas where marine mammals and sea turtles concentrate and where intensive ship surveys, that include both visual and acoustic sampling, could be more efficiently conducted. Aerial surveys are expensive (thousands of dollars per day) but less so than shipboard surveys. Cost: Medium to High. Priority: 2.

  - Continue to support aerial surveys over beaches where sea turtles are known to nest by focusing on specific locations and obtaining data from which population-level extrapolations can be made. Cost: Medium. Priority: 2.

  - Conduct aerial surveys designed specifically to spot endangered sea turtles in the water in their foraging habitats. Index studies, in which specific locations are sampled repetitively in a systematic fashion over a long period of time, provide statistically robust data from which population-level extrapolations can be made. Important population-scale questions can only be answered by rigorous studies of index foraging habitats. The data collected would provide important information on hotspots utilized by sea turtles while at sea. Cost: Medium. Priority: 2.

➢ Conduct quarterly manatee-directed aerial surveys over coastal waters and bays using standardized survey methods. Boat surveys should be conducted concurrently with these aerial surveys in order to better sight manatees, develop photo-identification catalogues, and obtain biological samples (e.g., tissue biopsies for genetic analyses). Cost: Medium. Priority: 2.

- Encourage ongoing investigations of the trophic ecology and behavior of the endangered West Indian manatee. Adequate protection of manatees hinges on understanding their use of seagrass beds and freshwater sources in the area. The continued use of satellite-linked tags to track individual manatees would help address some of these questions, in particular, habitat utilization. Cost: Low to Medium. Priority: 3.

- Archive species-specific sounds from cetaceans collected during NMFS acoustic shipboard surveys. These data could be the baseline used to identify sounds of unknown origin and for identifying and enumerating cetacean sounds recorded when visual observations are not possible (e.g., during inclement weather or at night) or from autonomous recording devices. This would provide additional information on the distribution of protected whales and dolphins in the PROA/St. Croix OPAREA. Similarly, anthropogenic sound recorded during the surveys may serve as the baseline from which to monitor the variety and location of noise (such as commercial shipping and other human activities). Development of "recognition" software is needed to compare and match sounds of unknown origin with those from known sources. Cost: Medium to High. Priority: 2.

- Establish year-round acoustic monitoring of key locations on the Puerto Rican Platform (e.g., the Mona Passage, the Virgin Passage) to provide presence and absence information for specific cetacean species (i.e., humpback whale) that could serve as an index of their seasonal arrival, residence, and departure from this region. Such acoustic monitoring could be conducted from small vessels, from bottom-mounted recorders or hydrophone arrays cabled to shore, or some combination of acoustic monitoring methods. Cost: Medium to High. Priority: 2.

- Utilize satellite-tracking technology to monitor the movements of endangered whales, such as the humpback whale and the sperm whale. Learning about the movements of individual whales, particularly humpback whales making return migrations to their feeding grounds, would provide valuable information on the possible locations of these species in deepwater areas that have not been well surveyed (if it all). This information is vital for assessing the occurrence and movements of whales for any potential mitigation efforts. Satellite-tracking programs are expensive, precluding the study of more than a few individuals. While insights on an individual's behaviors or movements may be gained, questions at the population level may go unanswered. Cost: Medium. Priority: 2.

- Support the Caribbean Stranding Network (CSN) and analysis of their collected data. Stranding network data was utilized in this MRA to aid in determination of species diversity and occurrence in the OPAREA. The CSN collects data on life history parameters, such as diet and reproduction; assists with stock determination by collection of tissue samples; and assesses human impacts on protected marine mammals and sea turtles. Photographs of stranded humpback and other whale species can supplement aerial surveys in the detection of movement patterns and assist with stock determination. Cost: Low. Priority: 2.

- Monitor coral reefs, particularly those adjacent to Navy lands. The Navy currently supports an extensive baseline survey of the Vieques Island coral reef ecosystem. By subsequently monitoring the Vieques and other coral reef areas within the OPAREA, any changes in the community structure or health can readily be determined. A monitoring program should consist of: (1) yearly qualitative analysis of coral reef sites to evaluate gross changes in the status and health of the reefs, and (2) complete resampling of all the Vieques coral reef sites with a frequency of two years to quantify changes in status and health of the reefs. Cost: High. Priority: 3.

- Survey OPAREA waters to determine the distribution of pelagic *Sargassum* spp. *Sargassum* is an important habitat for hatchling and juvenile sea turtles and many species of fishes. There is, however, relatively little information on the distribution of *Sargassum* in the scientific literature, particularly for the Caribbean Sea. By mapping the distribution of *Sargassum*, much could also be learned about the available habitat for the associated organisms. Dedicated survey cruises for *Sargassum* are expensive. Collection of data on *Sargassum* distribution would be ideal for platforms-of-opportunity, such as merchant ships and Navy vessels, or in conjunction with NMFS shipboard and aerial surveys. Cost: Low to High. Priority: 3.

- Develop a seagrass restoration and monitoring program to maintain a viable seagrass habitat for utilization by a suite of organisms including protected species such as manatees and sea turtles, which depend upon this sensitive habitat for survival. A transplanting program at the impacted Inner Range seagrass beds on Vieques Island would allow restoration in a controlled environment while, at the same time, displaying the Navy's stewardship and understanding of the sensitive habitats under its control. Cost: High. Priority: 3.

- Map the submarine physiography offshore of the Puerto Rico Platform to obtain higher resolution bathymetry data. Either dedicated surveys or surveys conducted in conjunction with marine mammal shipboard sighting and acoustic surveys would facilitate this. Side-scan or multiple beam side-scan sonar systems would accurately map the physiography of the ocean bottom acoustically. This higher resolution data would be extremely useful in understanding the distribution of protected species, such as beaked whales and endangered sperm whales that are most frequently found in deep waters, as well as for Navy operations and training. The cost of this deepwater mapping initiative would range from very expensive for dedicated cruises (thousands of dollars per day for ship, staff, and equipment) to moderately expensive for data collection efforts associated with existing survey cruises and/or transiting Navy ships (hundreds of dollars per day for staff and equipment). Cost: Medium to High. Priority: 3.

  - The deployment of expendable bathythermographs (XBTs) from Navy ships transiting the PROA/St. Croix OPAREA would also provide valuable oceanographic data. This approach would be similar to the successful "ship-of-opportunity" program where hydrographic data are collected aboard commercial merchant vessels. Cost: Low. Priority: 3.

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9.0 GLOSSARY

Abundant—an indication of the plentifulness of a species at a particular place and time; an abundant species is more plentiful than an occasional or rare species

Abyssal plain—flat, sediment-covered part of the ocean floor between the continental rise and the mid-ocean ridge at a depth greater than 4,000 to 5,000 m

Accidental—in the case of sea turtles, accidental means they have been recorded only a time or two; it is so far from its usual range, that further observations are considered unlikely; extralimital

Adult—having arrived at sexual or physical (full size and strength) maturity

Aggregation—group of animals that forms when individuals are attracted to an environmental resource to which each responds independently; the term does not imply any social organization

Ahermatypic coral—non-reef building coral that lack symbiotic zooxanthallae and are not restricted by depth, temperature, or light penetration; may be solitary or colonial

Anomaly—something irregular or abnormal

Anthropogenic—describing a phenomenon or condition created, directly or indirectly, as a result of human activity

Aquatic resources—plants and animals that live in the water or that are entirely dependent upon the water to survive; living resources found in aquatic habitats

Archipelagic baseline—the baseline from which the territorial seas of an archipelagic (chain of islands) island country are measured

Artificial reef—a human-made, marine habitat (sunken ships, concrete igloos, rubble) created in the navigable waters of the U.S. or in waters overlying the continental shelf to attract aquatic life

Artisanal—primarily small-scale fishing that is not sport fishing but includes both subsistence and small-scale commercial fishing

Ascidians—sea squirts; taxonomic class of globular or cylindrical animals that inhabit shallow and deep water, attach themselves to substrates (rocks, pilings, the bottom of ships, and coral reefs), and may be solitary or colonial

Assemblage—the populations of various species from a larger taxon characteristically associated with a particular environment that can be used as an indicator of the environment

Audiogram—a hearing sensitivity curve drawn as a function of frequency; measures the hearing ability of an animal

Autotroph—an organism that produces or synthesizes the organic materials they require from inorganic sources; organisms, such as plants, that produce their own carbon are autotrophs

Bacterioplankton—marine bacteria found in the water column; includes free and attached bacteria (i.e., marine snow)

Baleen—the interleaved, hard, fibrous plates made of keratin (protein in human fingernails and hair) that hang in rows side by side from the upper jaw of a mysticete whale; baleen takes the place of teeth and serves to filter the whale's food from the water

Baseline—the line from which maritime boundaries (EEZ, contiguous zone, territorial waters) are measured; in the U.S., the baseline is the low tide line except at the mouths of inland water bodies (bays) where a closing line (straight line) is drawn

Bathymetry—the topography of the ocean floor; study and mapping of ocean depths

Behavioral audiogram—a graphic representation of an animal's auditory threshold that is determined by tests with trained animals; measures the hearing ability of an animal

Benthic—organisms living on or near the ocean floor; the term is used irrespective of whether the sea is shallow or deep

Benthopelagic—the ecological zone from the seabed to 100 m above the seabed

Biomass—the amount of living matter per unit of water surface or water volume

Bloom—the usually seasonally dense growth of algae or phytoplankton that may be triggered by a high nutrient concentration or increased light

Blow—air exhaled through the blowhole of a cetacean mixed with surrounding water that is displaced by the exhalation

Blowhole—the nostrils or nasal openings on top of the head of a cetacean

Blubber—a specialized layer of fat found between the skin and underlying muscle of many marine mammals; it is used primarily for insulation and energy storage

Bottlenose dolphin—the former common name for *Tursiops truncatus,* now called the common bottlenose dolphin

Bruminate—the behavior exhibited by sea turtles of burrowing into bottom sediments to escape cold water conditions

Bryozoan—phylum of small, aquatic colonial animals that are commonly called moss animals; each zooid or animal in the colony has a crown of ciliated tentacles

Calving—the process of giving birth by a whale, dolphin, porpoise, or manatee

Cape—a darker region on the back of many species of dolphins and small whales, generally with a distinct margin

Carapace—the outer covering of the back of a sea turtle, which is bony for all sea turtle species with the exception of the leatherback, which has a leathery covering

Carbonate—type of rock or sediment formed of carbonate (CO_3^{-2}) and another element such as calcium or magnesium; limestone and dolomite are common carbonate rocks

Caribbean Sea—the body of seawater that is nearly enclosed by the land of the Greater and Lesser Antilles Islands on the northern and eastern sides and by South America and Latin America on the southern and western sides

Carnivore—an animal that feeds exclusively on another animal's tissue

Centripetal—moving or pulling toward a center or axis

Cephalopods—any predatory marine mollusk of the class Cephalopoda, with the mouth and head surrounded by tentacles (squid, octopus, cuttlefish)

Cetaceans—whales, dolphins, and porpoises

Chevron—V-shaped stripes

Chutes—an inclined channel found in the ocean floor

Circumglobal—the distribution pattern displayed by organisms around the world, within a range of latitudes

Clastic—a type of sediments or rocks composed of fragments derived from pre-existing rocks or minerals that have been transported a good distance from their place of origin

Click—a broad-frequency sound used by toothed whales for echolocation and may serve a communicative function; usually with peak energy between 10 kHz and 200 kHz

Clutch—a total number of eggs from one nesting

Cnidarians—the phylum of animals that includes corals, sea fans, sea anemones, hydroids, and jellyfish; known for the stinging cells on their tentacles these animals exhibit two body types, polyps or medusa, sometimes at different periods of one species development

Coast—the boundary where land and water meet

Coastal water—water that is along, near, or relating to a coast

Cochlea—a spiral structure in the inner ear that looks like a snail shell and contains over 10,000 tiny hair cells that move in response to sound waves; these movements stimulate nerve cells to send messages to the brain, which the brain interprets as sound

Coda—a patterned series of 3 to 20 clicks lasting about 0.5 to 2.5 seconds, used by sperm whales for communication

Cold-stunning—the behavior exhibited by sea turtles in response to cold water temperatures; turtle becomes lethargic and adopts a stunned floating posture

Common—in the case of sea turtles, common means that sea turtles have been recorded in all, or nearly all, proper habitats but some areas of the presumed habitat are occupied sparsely or not at all and/or the region regularly hosts large numbers of the species

Concentrated occurrence—a subarea of a species' expected occurrence, where there is the highest likelihood of encountering that species; based primarily on concentrated sightings and habitat preference

Conspecific—member of the same species and, in many cases, the same age or sex

Continental margin—the boundary or transition between the continents and the ocean basins that consists of the physiographic provinces of the continental shelf, continental slope, and continental rise

Continental rise—the province of the continental margin with a sloping seabed (1:100-1:700 gradient change) and a generally smooth surface, which lies between the abyssal plains and continental slope

Continental shelf—the province of the continental margin with a gently seaward-sloping seabed (1:1000 gradient change) extending from the low-tide line of the shoreline to 100 to 200 m water depth where there is a rapid gradient change

Continental shelf break—the area where the slope of the seabed rapidly changes from gently sloping to steeply sloping and the continental shelf gives way to the continental slope

Continental slope—the province of the continental margin with a relatively steeply sloping seabed (1:6 to 1:40 gradient change) that begins at the continental shelf break (about 100 to 200 m) and extends down to the continental rise; along many coasts of the world, the slope is furrowed by deep submarine canyons

Copepods—very small planktonic crustaceans present in a wide variety and great abundance in marine habitats, forming an important basis of ecosystems; they are a major food of many marine animals and are the main link between phytoplankton and higher trophic levels

Coral reef—a massive, wave-resistant structure built largely by colonial, stony coral via deposition of calcium carbonate

Coriolis effect—results from the Earth's rotation which causes objects in motion to be deflected to the right in the northern hemisphere and to the left in the southern hemisphere (centripetal force)

Cosmopolitan—having a broad, wide-ranging distribution

Crinoid—class of sessile echinoderms commonly called sea lilies and feather stars; these animals have a cup-shaped body that attaches to the substratum by a stalk (sea lilies) and have with feathery arms

Critical habitats—the portion (minimum) of the habitat that is essential for the survival for certain protected species (whales or sea turtles) and may include areas essential for feeding or reproduction by those species

Crustaceans—arthropods that have two pairs of antennae and a hard exoskeleton; lobster, shrimp, and crabs are the most familiar examples

Cyclonic—counter-clockwise circulation in the Northern Hemisphere or clockwise in the Southern Hemisphere; in oceanography, synonymous with cold-core ring

dB re 1 μPa-m—received underwater sound energy density level or underwater sound pressure level; units for underwater sound pressure measured in decibels at the reference level of one micopascal at one meter reference distance away from an ideal point sound source radiating the same amount of sound as the actual source

Deep scattering layer—a layer of a dense aggregation of fishes, squid, and other species found at depth that migrate vertically in the water column each day; the layer moves toward the surface at night to feed and returns to depth at dawn

Deepwater—the area of the ocean that is past the continental shelf break; greater than 200 m of water depth

Delimitation—fixing a boundary

Demersal—applied to fish that live close to or on the sea floor, such as cod and hake

Demographic—relating to or describing population levels or characteristics

Demography—birth and death rates that determine a population's dynamics; abundance, age, and sex structure of the population and reproductive status and life cycle of individuals

Density—physical property measured by mass per unit volume; in biology, the number of organisms per unit of area or distance

Detritivore—an animal that feeds on dead material (detritus)

Diel—refers to 24-hour activity cycle based on daily periods of light and dark

Diurnal—active or occurring during daylight hours; having a daily cycle

Dominant species—species most prevalent in a particular community, or at a given period

Dorsal—relating to the upper surface of an animal

Dorsal fin—the structure on the back of most cetaceans (not supported by bone); some species only have a dorsal hump or ridge, others have no hint of a dorsal structure

Downwelling—downward movement or sinking of surface water towards the ocean bottom; may be caused by convergent currents or density differences

Echinoderms—phylum of marine invertebrates with radial symmetry, a calcareous endoskeleton, and a water vascular system; sea stars and sea urchins are common examples

Echolocation—the production of high-frequency sound waves and reception of echoes to locate objects and investigate the surrounding environment

Ecosystem—a system of ecological relationships in a local environment comprising both organisms and their nonliving environment, intimately linked by a variety of biological, chemical, and physical processes

Eddy—a circular movement of water

El Niño—wind-driven reversal of the Pacific equatorial currents resulting in the movement of warm water towards the coasts of the Americas, considered a natural cyclical atmospheric/oceanic phenomenon; El Niño is often termed the El Niño/Southern Oscillation or "ENSO"

Endangered species—any animal or plant species in danger of extinction throughout all or a significant portion of its range; the authority to list a species is shared by the USFWS (plants and animals on land) and NMFS (most marine species) under provisions of the ESA

Enter into force—point in time from which the treaty is enforced for those states that gave consent

Entrainment—the process of picking up and carrying along

Environmental impact statement (EIS)—a detailed written statement that helps public officials make decisions that are based on understanding of environmental consequences and to take actions that protect, restore, and enhance the environment

Epibenthic—refers to organisms living on the bottom of the ocean floor

Epipelagic—the oceanic zone from the surface to 200 m

Epiphyte—a plant that grows on top of or is supported by another plant but does not depend on it for nutrition

Equidistant line or equidistance—a median line, every point of which is the same distance from the nearest points on the baselines of two countries

Escarpment—a steep slope in topography, as along the continental slope, generally separating two elevated levels

Essential fish habitat (EFH)—those habitats necessary to fish for spawning, breeding, feeding, or growth to maturity; designated by the NMFS

Estuary—a semi-enclosed body of water where freshwater mixes with saltwater; often an area of high biological productivity and important as nursery areas for many marine species

Euphotic zone—the uppermost area of the ocean (up to 150 m) that is sufficiently illuminated to permit photosynthesis by phytoplankton, algae, and submerged vegetation

Eurythermal—an organism that can tolerate a wide range of temperatures

Exclusive economic zone (EEZ)—encompasses the area from the baseline (usually the low-tide line) of a country outward to 200 NM except in areas where another country lies closer than 400 NM (e.g., Mediterranean Sea); within this zone or area, each country maintains sovereignty over all natural resources and has the jurisdiction to protect the marine environment

Expected occurrence—an area encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and behavior and the available stranding, sighting, and incidental fisheries bycatch data

Extralimital—outside the normal limits of an animal's distributional range

Extrapolate—to estimate a value that falls outside a range of known values

Fauna—animal life of a region

Falcate—sickle-shaped and curved (refers to the dorsal fin of some cetaceans)

Fathom—a marine distance unit, usually associated with water depths; one fathom equals 1.83 m

Fish aggregating device (FAD)—single or multiple floating structures that are connected to the ocean floor by ballast or anchors; used to attract fish

Flora—all the plant species that make up the vegetation of a given area

Flukes—the horizontally spread tail of a cetacean

Forage—search for food

Free diver—a diver who does not use scuba equipment but instead, simply holds his/her breath

Fusiform—spindle-shaped or torpedo-shaped and tapering at one or both ends

Gape—the mouth in cetaceans, usually referring to the junction of upper and lower lips

Gastropods—class of symmetrical, univalve mollusks that have a true head, an unsegmented body, and a broad, flat foot

Gestation—period of development in the uterus from conception until birth (pregnancy)

Gillnet—a type of fishing gear that consists of a rectangular panel of mesh set more or less vertically in the water so that fish swimming into it are entangled by their gills; they can fish at the surface, at mid-water, or on the bottom of the water column

Gorgonians—any of the various corals of the order Gorgonacea; sea fans

Greater Antilles—the islands in the northern Caribbean Sea that include Cuba, Hispaniola, Jamaica, and Puerto Rico

Gregarious—used to describe organisms that form groups

Gyre—circular movement of waters, larger than an eddy; usually applied to oceanic systems

Habitat—the living place of an organism or community of organisms that is characterized by its physical or living properties

Habitat preference—the choice by an organism of a particular habitat in preference to others

Hard bottom community—area of ocean bottom habitat with three-dimensional character providing physically stable shelter and substrate for large populations of sessile, or permanently attached, invertebrates and fishes

Hatchling—a newly hatched bird, amphibian, fish, or reptile

Haven—refuge or sanctuary

Herbivore—an animal that eats plants as its main source of energy

Hermatypic coral—reef-building coral containing symbiotic, unicellular zooxanthallae in their endodermal tissue; usually colonial, may be solitary, found in shallow, warm, sunlit waters

Holdfast—an organ at the base of a seaweed, aquatic plant, or fungus that attaches the organism to a surface

Holopelagic—a member of the plankton for an animal's entire life cycle

Hydrography—the science of measuring and describing the surface waters of the Earth

Hydroid—class of solitary or colonial coelenterates that have a hollow cylindrical body closed at one end with a mouth surrounded by tentacles at the other end

Hydrophone—transducer for detecting underwater sound pressures; an underwater microphone

Ichthyofauna—all fish that live in a particular area

Ichthyoplankton—fish eggs and larvae drifting in the water column

Incidental fisheries bycatch—the catch of additional species, such as fishes, turtles, or marine mammals that is not targeted by a fishery but is taken along with the species being sought (target species)

Infrasonic—sound at frequencies too low to be audible to humans, generally below 20 Hz

Inshore—lying close to the shore or coast

In situ—in the natural or original position

Insular—pertaining to or situated on an island

Inter-nesting interval—the amount of time between successive sea turtle nesting events during the nesting season

Interpolate—extrapolation to predict values for a parameter between limited data points

Intertidal—the area of shore exposed between high and low tide

Irruptive—entering an area where not characteristically seen

Isobath—bathymetric contour of equal depth; usually shown as a line linking points of the same depth

Isohaline—contour of equal salinity, usually shown as a line connecting points of the same salinity

Isotherm—contour of equal temperature; usually shown as a line linking points of the same temperature

Juvenile—mostly similar in form to adult but not yet sexually mature; a smaller replica of the adult

***Kogia*—**the genus of pygmy and dwarf sperm whales

Lactation—secretion or formation of milk by the mammary glands for the purpose of nursing offspring

La Niña—when ocean temperatures in the eastern equatorial Pacific are unusually cold; it is essentially the opposite of the El Niño phenomenon; La Niña sometimes is referred to as the cold phase of an ENSO

Leeward—part or side sheltered from the wind or weather; side away from the wind

Lesser Antilles—the small islands in the eastern Caribbean Sea stretching in a north to south direction from the Virgin Islands to Trinidad and then in an east to west direction from Margarita to Aruba off the northern coast of Venezuela

Littoral—a shore or coastal region, particularly the zone between the high and low tide marks

Live bottom community—a concentration of benthic invertebrates and demersal fishes that are associated with a region of vertical relief and structural complexity; such oasis-like communities are often surrounded by expanses of little relief and structure; the physical structure of these communities can be both organic (e.g., coral skeletons) and inorganic (e.g., rocks) in origin

Longline—a buoyed line onto which are attached numerous branch lines each terminating in a baited hook; longlines may extend for tens of kilometers and are usually left to drift in surface waters or near the sea floor

Lost year—the early juvenile stage (first years of life) of most sea turtle species that is spent far offshore; few turtles are observed during this time

Low/unknown occurrence—an area where the likelihood of encountering a species is rare or not known

Macroplankton—the component of plankton that consists of relatively large organisms, which are 20 to 200 mm in diameter

Mangrove—a variety of salt-tolerant trees and shrubs that inhabit the intertidal zones of tropical and subtropical regions; tropical equivalent of salt marshes

Map projection—a mathematical formulation that transforms feature locations on the Earth's curved surface (three dimensions) to a map's flat surface (two dimensions)

Mean—(arithmetic) average

Melon—a fatty cushion forming a bulbous "forehead" in toothed whales; may act to focus sound for echolocation

Mesopelagic—occurring in the oceanic zone from 200 to 1,000 m

***Mesoplodon*—**a genus of beaked whales, which includes the Blainville's beaked whale, Gervais' beaked whale, Sowerby's beaked whale, and True's beaked whale

Mesoscale—large scale

Metabolism—the biochemical reactions that take place in an organism

Metadata—information about a geographic information system (GIS) shapefile or coverage file that describes the source of the data or information, the creation date, the data format, the projection, the scale, the accuracy, and the reliability of the GIS file with regard to some standard

Migratory—seasonal movements of a complete population of organisms to more favorable habitat

Morphology—the form and structure of an organism considered as a whole; appearance

Morphometric—the study of comparative morphological measurements

Mysticeti—suborder of cetaceans comprised of the baleen whales

Nautical mile (NM)—a distance measure in the marine environment and is equal to one minute of latitude or 1.85 km

Nearshore—an indefinite zone that extends seaward from the shoreline

Neonate—a newborn

Neritic zone—the shallow pelagic zone over the continental shelf; usually no deeper than 200 m

Nocturnal—applied to events that occur during nighttime hours

North Atlantic—the part of the Atlantic Ocean found north of the Equator

Northwest Atlantic—the part of the Atlantic Ocean found north of the Equator and west of the mid-ocean ridge (or roughly the area between Iceland and Greenland); synonymous with western North Atlantic Ocean

Occurrence not expected—an area where a species is not expected to be encountered

Occurrence record—a marine mammal or sea turtle sighting (aerial or shipboard survey), stranding, incidental fisheries bycatch, nesting, or tagging data record for which locational information is available. An occurrence record, especially sighting occurrence records, may represent the occurrence of one or multiple animals of a particular species; for instance, one occurrence record from a marine mammal sighting survey in the PROA/St. Croix OPAREA indicated that 34 short-finned pilot whales were observed at a location but this information would be plotted on a map figure as one occurrence record

Ocean front—a boundary between two water or air masses that have different densities; water density differences are caused by differences in temperature or salinity

Oceanic zone—the part of pelagic waters away from shore but in open water; past the continental shelf

Oceanography—the scientific study of the oceans, including their chemistry, biology, geology, and physics

Odontoceti—the suborder of cetaceans comprised of toothed whales (e.g., beaked whales, dolphins, porpoises, sperm whales)

Offshore—open ocean waters over the continental slope that are deeper than 200 m; water beyond the continental shelf break

Olfactory—relating to the sense of smell

Oligotrophic—water that is lacking in nutrients but rich in dissolved oxygen

Omnivore—an animal that feeds on both plant and animal tissue

Opportunistic—used to describe organisms that take advantage of all feeding opportunities and do not prey on a few specific items

Optimum sustainable population—with respect to any population stock, the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element

Overfish—a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis

Overwinter—staying the winter in one area

Pectoral fin—flipper; flattened fore-limb of a cetacean (supported by bone)

Pelagic—primary division of the sea that includes the whole mass of water subdivided into neritic and oceanic zones; also pertaining to the open sea

Penaeid—a group of shrimp, chiefly found in warm water

Photic zone—the uppermost zone in the water where sunlight permits photosynthesis

Photosynthesis—the chemical process using chlorophyll that plants and algae use to convert solar energy into organic matter (cellular energy) by synthesizing water and carbon dioxide

Physiography—physical geography of the ocean bottom and continental margins

Phytoplankton—microscopic, photosynthetic plankton, which are the base of the food chain on which ultimately most shellfish, fish, birds, and marine mammals depend

Pinnacle—on the seafloor, a high tower or spire-shaped pillar of rock or coral, along or cresting a summit

Pinnipeds—seals, sea lions, and walruses

Planktivore—an animal that feeds on plankton

Plankton—organisms (plant or animal) that drift in the water column and cannot propel or move themselves

Plastron—bony shield composing the ventral side of a turtle’s shell

Population—a group of individuals of the same species occupying the same area

Posterior—situated near or toward the back of an animal's body

Pot/trap—a type of static, baited fishing gear used to capture fish or crustaceans (lobsters and crabs); pots and traps are made of many types of materials (wood, reeds, or wire) and are found in many shapes or configurations; the terms "pot" and "trap" are fairly synonymous but may be used exclusively in specific fisheries. Structurally, pots/traps allow entry but exit is impossible, and the trapped fish or crustacean remains alive until the pot/trap is hauled to the surface

Practical salinity unit (psu)—the currently used dimensionless unit for salinity, replacing parts per thousand (ppt)

Primary producer—an autotroph or organism able to utilize inorganic sources of carbon and nitrogen as starting materials for biosynthesis; uses either solar or chemical energy

Propagule—a part of a plant or fungus such as a bud or a spore that becomes detached from the rest and forms a new organism

Pup—a young animal of various species; in this case, refers to young pinnipeds

Pupping—the process of giving birth by pinnipeds

Purse seine—a large commercial fishing net pulled by two boats, with ends that are pulled together around a shoal of fish so that the net forms a pouch or "purse"

Rare—a plant or animal restricted in distribution or number; in the case of sea turtles, rare means that a species occurs, or probably occurs, regularly within the region but in very small numbers

Ratify—to affirm or approve; in the case of a treaty, to agree to be bound by the treaty

Recreational fishing—fishing for sport or pleasure

Relief—the inequalities (elevations and depressions) of the sea bottom

Remigration interval—the amount of time between successive sea turtle nesting seasons

Rhizome—an elongated underground stem that produces roots below the soil surface and leaves above the soil surface

Robust—powerfully built

Rorqual—any of six species of baleen whales (the minke, blue, humpback, fin, Bryde's, or sei whale) belonging to the family Balaenopteridae; characterized by a variable number of pleats that run longitudinally from the chin to near the umbilicus; the pleats expand during feeding to increase the capacity of the mouth

Rostrum—the snout or beak of a cetacean; in fish, a forward projection of the snout

Saddle—a light-colored patch behind the dorsal fin of some cetaceans

Salinity—the concentration of salt in water, measured in practical salinity units (psu)

Sargasso Sea—the oligotrophic central portion (North Atlantic gyre) of the North Atlantic Ocean bounded in the west by the Gulf Stream

***Sargassum*—**a genus of brown algae commonly found in temperate and tropical waters

School—a group of fish drawn together by social attraction, whose members are usually of the same species, size, and age; the members of a school move in unison along parallel paths and in the same direction

Scleractinian—hard-rayed corals, dominant in reef ecosystems, known as true corals, having a compact calcareous skeleton and polyps with no siphonoglyphs (grooves)

Scutes—long, thickened scales that cover underlying bony plates of carapace and plastron of sea turtles that are used for protection

Sea anemones—large, heavy, complex polyps that belong to the cnidarian class Anthozoa

Sediment—solid fragmented material, either mineral or organic, that is deposited by ice, water, or air

Sessile—used to describe an animal that is attached to something rather than free moving

Sexually dimorphic—differences in the appearance of the sexes of a species; size differences are a primary difference where males are generally larger than females; other differences may be in body shape and color

Shallow water—water that is between the shore and the continental shelf break or shallower than 200 m

Shelf break (continental)—region where the slope of the seabed rapidly changes from gently sloping to steeply sloping and the continental shelf gives way to the continental slope; on average, this change occurs at approximately 100 to 200 m in water depth

Shelf break region—the geographic area surrounding the continental shelf break and including both the outer continental shelf and upper continental slope

Shoals—a submerged ridge, bank, or bar consisting of, or covered by, unconsolidated sediments (mud, sand, gravel) which is at or near enough to the water surface to constitute a danger to navigation

Sirenia—the order of marine mammals that consists of manatees and the dugong

South Atlantic—the part of the Atlantic Ocean found south of the Equator; the NMFS and the general public often erroneously refer to the region between Cape Hatteras and Cape Canaveral as the South Atlantic, which however commonly used, is incorrectly applied

Spawn—the release of eggs and sperm during mating

Species—a population or series of populations of organisms that can interbreed freely with each other but not with members of the other species

Species diversity—the number of different species in a given area

Standard deviation—a statistical measure of the amount that a set of numerical values differs from their arithmetical mean; in other words, how widely numerical values are dispersed from the average

***Stenella*—**the genus of oceanic dolphins consisting of striped, Atlantic spotted, pantropical spotted, Clymene, and spinner dolphins, which are similar in appearance

Stenellid—refers to dolphins of the genus *Stenella*

Stock—a group of individuals of a species that can be regarded as an entity for management or assessment purposes; a separate breeding population of a species

Stock structure—the genetic diversity of a stock

Straight carapace length—the body length of sea turtles; it is a straight-line measurement from the rear of the eye socket parallel to the center line of the carapace to the posterior edge of the carapace

Stranding—the act where marine mammals or sea turtles accidentally come ashore, either alive or dead

Strategic stock—any marine mammal stock: (1) from which the level of direct human-caused mortality exceeds the potential biological removal level; (2) which is declining and likely to be listed as threatened under the ESA; or (3) which is listed as threatened or endangered under the ESA or as depleted under the MMPA

Subadult—maturing individuals that are not yet sexually mature

Subpopulations—an identifiable fraction or subdivision of a population

Substrate—the substance or nutrient on or in which an organism grows, or the surface on which a sessile organism is attached

Subtropical—the regions lying between the tropical and temperate latitudes

Symbiosis—the interrelationship between individuals of two different species; both species usually benefit in a symbiotic relationship

Sympatric—species or subspecies occurring together; having overlapping areas of distribution

Taxa (taxon)—a defined unit (e.g., species, genus, or family) in the classification of living organisms

Taxonomy—the study of the rules, principles, and practice of classifying, especially living organisms

Temperate—inhabiting the mid-latitudes characterized by a mild, seasonally changing climate

Terrigenous—derived from land or a continent

Thermocline—the depth in the ocean in which the temperature decreases rapidly

Thermohaline circulation—density-driven water circulation caused by differences in temperature and/or salinity

Threatened species—any plant or animal species likely to become endangered within the foreseeable future throughout all or a part of its range; the authority to list a species is shared by the USFWS (plants and animals on land) and NMFS (most marine species) under provisions of the Endangered Species Act

Topography—physical features of the ocean floor, such as mountains or canyons

Trawl net—a towed net with a cod-end or bag for collecting the fish or other target species; they can be towed at any depth of the water column

Trophic level—a step in the transfer of food or energy within a chain

Tropical—the geographic region found in the low latitudes (30° north of the equator to 30° south of the equator) characterized by a warm climate

***Tursiops*—**the genus of bottlenose dolphins comprised of the common bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)

Upwelling—upward movement or rising of deep, usually nutrient- and oxygen-rich water to the surface to replace surface waters that have moved to another location; may be caused by wind-forcing, divergent currents, or density differences

Ventral—relating to the lower surface (belly) of an animal

Vertebrates—animals with a backbone

Water column—a vertical column of the seawater extending from the surface to the sea bottom

Water mass—a body of water that can be identified by its temperature and salinity

Weed line—line of floating algae usually concentrated by the wind or currents

West Indies—the islands in the Caribbean Sea composed of the Greater and Lesser Antilles

Western Boundary Current—strong, fast-moving current at the western boundary of an ocean (off the east coast of a continent); examples include the Gulf Stream and the Kuroshio Current

Western North Atlantic—the part of the Atlantic Ocean found north of the Equator and west of the mid-ocean ridge (or roughly the area between Iceland and Greenland); synonymous with Northwest Atlantic Ocean

Wetland—an area inundated by water frequently enough to support vegetation that requires saturated soil conditions for growth and reproduction; generally includes swamps, marshes, springs, seeps, or wet meadows; they can be fresh or saltwater

Whistle—a narrow band frequency sound produced by some toothed whales and used for communication; they typically have energy below 20 kHz

Zooplankton—ensemble of small floating animals that drift freely in the water column; the zooplankton is composed of a wide range of invertebrates and the larval forms of fish and shellfish

Zooxanthallae—single-celled algae living with a coral; this is what gives coral its color

APPENDIX A: INTRODUCTION

Data confidence and PROA/St. Croix OPAREA geographic information system maps..... Table A-1

Map projections ..... Appendix A-1

Overview of research efforts that provide occurrence information for marine mammals and sea turtles in the PROA/St. Croix OPAREA..... Appendix A-2

Sources for marine mammal and sea turtle data included in the MRA of the PROA/St. Croix OPAREA ..... Table A-2

Tracklines and transect coordinates of shipboard and aerial surveys in the PROA/St. Croix OPAREA and vicinity ..... Figure A-1

Table A-1. Data confidence and PROA/St. Croix OPAREA geographic information system maps.

The level of data confidence is dependent upon three factors: precision, accuracy, and currency. Each of these three factors are in turn affected by all the variables involved in obtaining data and putting it into a GIS in order to display the data on a map. Following is a brief description of the three main factors and some of the subsequent variables that figure into overall level of confidence.

- ***Precision***—Refers to whether or not the description of the data is specific or non-specific. It is possible to have data recorded very precisely but with very low accuracy. In other words we may say that 2 + 2 = 5.12546732, where the sum is given very precisely but inaccurately. Global Positioning System (GPS) offers the highest level of precision for recording locations.

- ***Accuracy***—Refers to how well the data reflect reality. There may be 10 sightings of harbor porpoises in an area but they may actually have been common dolphins. Even if the locations were precisely recorded, the data are still not accurate. Some variables that affect accuracy are who originally recorded the data (source reliability), how many people have processed/altered the data since it originated (number of iterations), and the method used to record the data.

- ***Currency***—Refers to how recently the data were obtained. Because recent developments in equipment and methods have improved precision and accuracy, confidence is higher for data that have been recorded more recently.

PROA/St. Croix Map Examples	Description of Map Data	Confidence Level
Marine mammal and sea turtle occurrences, bathymetry, chlorophyll, sea surface temperature, maritime boundaries, and marine protected areas	Data from original/reliable sources. Provided in a digital format with geographic coordinates given. Identified as "*source data*" in map captions.	**High** 45 maps (73% of total number of maps)
Benthic communities, turtle habitat, and some fisheries	First- or second-hand data sources. Locations obtained through scanning geo-referenced* maps. Identified as "*source map(s) scanned*" in map captions.	**Medium** 10 maps (16% of total map number)
Fisheries and *Sargassum* distribution	First- or second-hand data sources. Locations obtained by digitizing from written descriptions with no coordinate data or by altering and/or interpreting raw data. Identified respectively as "*source information*" or "*map adapted from*" in map captions.	**Low** 7 maps (11% of total number of maps)

*Geo-referenced–Refers to data, maps, and images with points that can be matched to real world coordinates so that the data can be accurately positioned in a GIS.

Appendix A-1. Map projections.

Since understanding the role map projections play in the creation of valid and usable maps is so critical, further explanation of this issue is provided here. A geographic reference system is based on the angles measured from the earth's center. A planar coordinate system, on the other hand, is based on measurements on the surface of the earth. To meaningfully transfer real world coordinates (in three dimensions) to planar coordinate (two dimensions), a transformation process has to be applied. This transformation process is called a projection. Such a transformation involves the distortion of one or more of the following elements: shape, area, distance, and/or direction. Choice of projections is therefore typically user dictated to ensure the least distortion to one or more of the four elements. Therefore projections are chosen to ensure that at least one of the four elements is preserved in the transformation. Choice of a particular projection is therefore dictated by issues such as the location of the place on earth, purpose of the project, user constraints, and others.

The length of one degree of longitude will vary depending on what latitude the measurement is taken. This is because the geographic system measures the angles from the center of the earth and not distances on the surface of the earth. One degree of longitude at the equator measures 111 kilometers versus 0 kilometers at the poles. Since the measurement units are not associated with a standard length, they cannot be used as an accurate measure of distance. The map scales and reference datum used on all maps in this marine resource assessment are presented in statute miles, not nautical miles. It is not currently possible to use nautical miles for the scale in ESRI's ArcView® geographic information system software.

Appendix A-2. Overview of research efforts that provide occurrence information for marine mammals and sea turtles in the PROA/St. Croix OPAREA

Attempts were made to compile all available records of strandings, shipboard and aerial survey sightings, and incidental fisheries bycatch of marine mammals and sea turtles from the PROA/St. Croix OPAREA to determine seasonal occurrence of those species. The following is intended to be a comprehensive review of the various research efforts, conducted and/or sponsored by federal and state agencies, directed to these protected species in the PROA/St. Croix OPAREA. For a variety of reasons, it was not possible to obtain the data from every known source; all sighting, stranding, fishery bycatch, and nest/track data that were available are included in this MRA report (Table A-2). The areal coverage of survey effort is greatest around the islands of Puerto Rico while the vast majority of the OPAREA has sparse data coverage (Figure A-1).

Table A-2. Sources for marine mammal and sea turtle data included in the MRA of the PROA/St. Croix OPAREA.

DATA	YEAR(S)
Shipboard Sighting Surveys	
NMFS-SEFSC *Gordon Gunter* Cruise GU-00-01 (marine mammals only)	2000
NMFS-SEFSC *Gordon Gunter* Cruise GU-01-01 (marine mammals only)	2001
NMFS-SEFSC *Oregon II* Cruise 215 (95-01) (marine mammals only)	1995
Sightings	
Mignucci-Giannoni marine mammal sighting database (including Rodriequez-Ferrer surveys)	1851-2002
Aerial Surveys	
Rathbun surveys (Rathbun et al. 1985)	1984-1985
ECOmap surveys (Mignucci et al. 2002)–sea turtles and manatees	2001-2002
Puerto Rico Legislature surveys (Mignucci et al. 2000)–sea turtles	2000
DoN/GMI Virgin Passage survey	2000
DoN/GMI Vieques Aerial surveys	2000-2002
Strandings	
Caribbean Stranding Network database (sea turtles)	1985-2000
Caribbean Stranding Network database (marine mammals)	1867-2002
PUBLISHED LITERATURE AND REPORTS	
Caldwell and Caldwell	1970

For a brief description of how aerial and shipboard surveys are conducted, see Henwood and Epperly (1999) and Forney (2002). Each type of survey platform has advantages and disadvantages. Ships are slow and expensive but they provide an opportunity to scan a particular location for a greater period of time than is usually possible from aircraft. Much larger geographic areas can be covered rapidly by aircraft but for only a relatively brief period. Aerial or shipboard observers collect line-transect data during daylight hours, weather-permitting (i.e., no rain, Beaufort sea state <4). Surveys are conducted along pre-designated transect lines following established sampling methods that allow for abundance estimates in an area of interest. Any animal(s) sighted while the observation platform (e.g., ship or plane) is traveling along the transect line (and observers are actively searching for animals) is “on-effort” and is included in

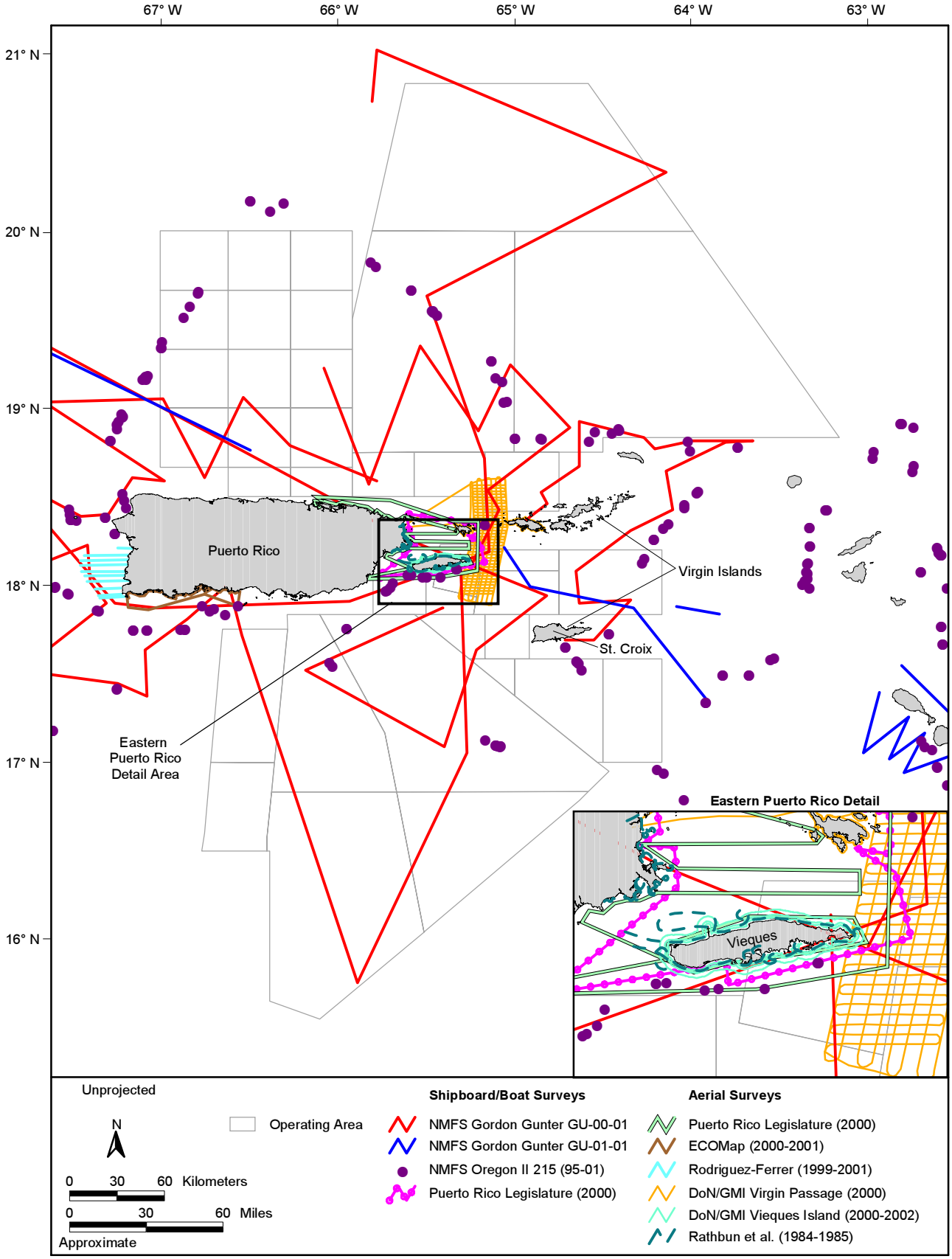

Figure A-1. Tracklines and transect coordinates of shipboard and aerial surveys in the PROA/St. Croix OPAREA and vicinity. Source data: NMFS-SEFSC. Source maps (scanned): Rathbun et al. (1985), Mignucci et al. (2000, 2002), Swartz and Burks (2000), Rodríguez-Ferrer (2001), and Swartz et al. (2002).

Appendix A-2. Continued

the abundance estimation. Any animal or group sighted while the observation platform is diverted from the transect line is recorded as "off-effort." Sightings made while the plane or ship is in transit to and from the actual survey transect line(s) are also considered off-effort. While off-effort sightings may not be used for abundance estimates, these sightings are useful in providing more information on the occurrence patterns of a species.

National Marine Fisheries Service Shipboard Sighting Surveys

Shipboard surveys conducted by NMFS are designed to collect data to address many informational needs. To meet the mandate established in Section 117 of the amended MMPA, the NMFS and the U.S. Fish and Wildlife Service (USFWS) must prepare, in consultation with regional Scientific Review Groups, assessments for each marine mammal stock that occurs in U.S. waters. These stock assessment reports contain several items, including a description of the stock and its distribution, as well as a minimum population estimate (Wade and Angliss 1997). One of the primary ways NMFS collects marine mammal population data to use in stock assessments is from shipboard surveys.

NMFS is also responsible for assessing and monitoring sea turtle stocks, which requires current distribution information and population estimates to establish temporal trends in the populations or stocks in U.S. waters. While shipboard surveys are not the optimal survey technique to gather sea turtle population data, sighting data from shipboard surveys often provide valuable information that can be used in the calculation of sea turtle abundance estimates.

- From **29 January to 8 March 1995**, the ***Oregon II* Cruise 215 (95-01)** was a visual survey designed to cover a broad range of water depths around Puerto Rico and the USVI (Roden and Mullin 2000). Objectives were to: (1) collect line transect data to estimate abundances and define the distributions of cetaceans in the northern Caribbean Sea and adjacent Atlantic Ocean; (2) collect ichthyoplankton samples in an Atlantic swordfish longline fishing area and throughout the survey area; (3) collect associated environmental data at designated stations; (4) obtain biopsy samples of skin and blubber from selected cetacean species in U.S. waters; and (5) collect data on the distribution and abundance of seabirds and other marine life (NMFS-SEFSC 1995). As noted by Mullin and Roden (2000), these surveys could only be conducted in deeper waters that skirt the banks or other shallow waters, so whales seen in shallow water were recorded as unidentified rorquals, although they were likely humpback whales.

- From **16 February to 29 March 2000**, the ***Gordon Gunter* Cruise GU-00-01** was a visual and passive acoustic survey conducted in the eastern and southern Caribbean Sea to assess the current distribution and status of the humpback whales in areas where it was previously hunted to depletion by commercial whalers and to evaluate the effectiveness of using visual and passive acoustic survey methods to assess humpback whales in this region (Swartz and Burks 2000; Swartz et al. 2001). The cruise track focused on the waters around the Leeward Islands (except for the USVI and BVI, the islands on Anguilla Bank, Sint Eustatius, Saba Island, and Saba Bank), the Windward Islands, Barbados, Tobago, Trinidad, the islands in the southern Caribbean north of Venezuela, and the Caribbean coast of Venezuela. While transiting to and returning from this study area, data were collected opportunistically from the waters north of Puerto Rico and the Dominican Republic in the eastern portion of the Greater Antilles (Swartz et al. 2001). The objectives of the survey were to: (1) assess current distribution and relative densities of humpback whales in historically important habitats; (2) photograph and biopsy sample humpback whales for individual identification, as well as toxicological and stable isotope analyses, to determine the relationship of these whales within the greater North Atlantic population; (3) opportunitistically obtain biopsy samples of other cetacean species, including Bryde's whales, sperm whales, and other odontocetes; (4) opportunistically collect data on the distribution and relative densities of seabirds and other marine life; and (5) collect associated environmental data at survey locations.

Appendix A-2. Continued

- From **12 February to 8 March 2001**, the ***Gordon Gunter*** **Cruise GU-01-01(11)** was a visual and passive acoustic survey to investigate the present winter abundance and distribution of humpback whales and other cetaceans wintering in the Lesser and Greater Antilles (Swartz et al. 2002). This was the first survey for marine mammals conducted under an Interagency Agreement between the Navy and the NMFS-SEFSC whereby the Navy provides funding to augment the NMFS-SEFSC's survey program allowing the collection of synoptic information on the seasonal abundance and trends of marine mammals throughout the U.S. southeast region (Swartz et al. 2002). The first leg began south of Abaco Island in the Bahamas and continued southward along the eastern side of the Bahamas past Caicos, Mouchoir, Silver, and Navidad Banks. This leg then continued southward along the Mona Channel, eastward along the southern side of Puerto Rico to Vieques Island, then continuing northward through the Virgin Passage and surveyed the insular shelf waters to the northeast of Puerto Rico and concluded at the Port of San Juan. The second leg included the insular and offshore waters to the north of Puerto Rico, including the southern portion of the Puerto Rico Trench, the insular shelf and offshore waters south of Puerto Rico, the Mona Channel including the coastal waters of the Dominican Republic, the insular shelf waters along the northwestern side of Puerto Rico, and insular shelf waters around the USVI. The objectives of the survey were to: (1) test the acoustic detection range and calibrate passive acoustic systems on the NOAA ship *Gordon Gunter* at the Navy's Atlantic Undersea Test and Evaluation Center (AUTEC) Acoustic Testing Range at Andros Island, Bahamas; (2) conduct visual line-transect and passive acoustic surveys to determine the winter distribution and abundance of cetaceans in the waters around Puerto Rico and the USVI; (3) collect recordings of vocalizations and other sounds from all cetacean species encountered for reference and comparison among regions; (4) collect associated environmental data at designated sites within the study area; and (5) deploy and retrieve two acoustic bottom recorders to test the feasibility of utilizing such devices for long-term acoustic monitoring at designated sites.

- **Texas A&M University opportunistic marine mammal survey** was conducted the summer of **1991** in the Gulf of Mexico, Caribbean Sea, and a small portion of the southwestern North Atlantic (Jefferson and Lynn 1994). The survey took place on the *Texas Clipper*, a Texas A&M vessel that sailed the world oceans every summer, and existed to train students as officers of the Merchant Marine. A total of 193 hours of survey effort were conducted. Two legs of the cruise went through the PROA/St. Croix OPAREA: 17 through 20 June (from Puerto Plata, Dominican Republic to San Juan, Puerto Rico) and 25 to 27 June (from San Juan, Puerto Rico, to Fort de France, Martinique). Unfortunately, no marine mammals were sighted while underway during these two legs.

Aerial Sighting Surveys

The typical goal of an aerial survey is to estimate an overall density or abundance of a given marine mammal or sea turtle population. Aerial surveys are appropriate when little is known about the distribution and abundance of a population or species over relatively large areas. Such surveys help identify "hot spots" for future studies. Surveys can then be conducted to monitor trends in seasonal or annual variations in distribution and abundance patterns. Aircraft are also used in fine-scale surveys of a sub-region of a study area. The objective of Navy-supported aerial monitoring is to detect all, or nearly all, of the marine mammals and sea turtles present to avoid impacting these protected species during Navy training exercises.

- **NMFS-SEFSC** conducted some aerial surveys around the islands of St. Thomas and St. Croix during August **1981** (Scott 1982 in Scott 1990). The purpose of the surveys was to assess the possible impact on the bottlenose dolphin population if a permit request to capture dolphins in the area for medical research in Florida was granted (Mignucci-Giannoni 1989). The results of the survey were inconclusive since, although present in the area, the dolphins were apparently not easily visible from the air, and very few sightings were recorded (Mignucci-Giannoni 1989). The dataset and report were requested from NMFS-SEFSC (Miami Laboratory); no response to the request was received.

Appendix A-2. Continued

- **Puerto Rico Department of Natural and Environmental Resources (DNER)** conducted aerial surveys to assess the distribution and abundance of manatees in Puerto Rico. These surveys were conducted by DNER in **August 1976 and monthly from June 1978 through March 1979** (Powell et al. 1981). Two surveys were flown in June 1978, but none were flown in July 1978 or January 1979. Interviews with coastal residents were also conducted. The entire coast of Puerto Rico and Vieques Island was flown. The second June 1978 survey covered only the coast from San Juan clockwise to the Guajataca River. The northern and southern coasts of western Vieques Island were not flown during the second **June and August 1978** surveys (Powell et al. 1981). The coast of Mona Island was surveyed only during August 1978. Surveys were flown in a Cessna 172; 10 surveys were completed (Powell et al. 1981). Powell et al. (1981) found that nearly a third of the manatee population in Puerto occurs at Naval Station Roosevelt Roads (NSRR).

- The **USFWS Caribbean Field Office** conducted aerial surveys from **1984 through 1999** (Lefebvre et al. 2001). Mignucci-Giannoni (1996) notes that these are quarterly surveys. Any positional information for manatee and sea turtle sightings is only handwritten on a map, often times with no information on the number of individuals sighted, or a date written on the sheet. This data would be considered highly unreliable, since it would not be possible to determine whether surveys from the same day were being entered as multiple surveys and hence multiple sightings.

- In **1978**, **Magor** (1979) conducted a study on the status, distribution, abundance, group structure, and aspects of the feeding ecology of manatees at Vieques Island. Aerial surveys of the coastal waters of Vieques Island and eastern Puerto Rico were conducted in fixed-wing aircraft and helicopters from 16 May to 8 June 1978. The south coast and northeast coast of Puerto Rico and the island of Culebra were surveyed once during this period from a fixed-wing aircraft. Vieques and NSRR were again surveyed on 30 August and 4 September 1978, once by helicopter and once by plane. Coordinates for sightings were not included in Magor (1979) nor provided to the Navy as part of the contract. Some sighting locations were estimated by Dr. Antonio Mignucci-Giannoni and included in his marine mammal-sighting database.

- The Navy contracted the Florida State Museum to conduct an aerial survey of manatees and sea turtles in the area of Naval Station Roosevelt Roads (NSRR) from **March 1984 through March 1985** (Rathbun et al. 1985). These surveys are often referred to as the **Rathbun surveys**. The objectives of the study were to: (1) document manatee and sea turtle distribution in the nearshore waters of NSRR and Vieques Island and relate these data to the distribution and abundance of these species around the entire island of Puerto Rico; (2) attempt to relate the distribution and abundance of manatees and sea turtles to habitat features, such as seagrass beds, sources of fresh waters, and climatic patterns. A Cessna 172 was used to survey the coast at NSRR and Vieques Island. The coast was flown about 0.5 km from shore. The entire coast of Puerto Rico was flown once a month for 12 months. The eastern half of Vieques Island was often restricted, resulting in uneven coverage of the island. These data are not available as electronic data and were only available as marked locations on a map (with no latitude/longitude provided). The maps were scanned and digitized and the data appears in this report.

- In 1984, the Navy entered into an agreement with the **USFWS** to develop a Natural Resources Management Plan (Diaz et al. 1992). The objective of this plan is to develop management strategies to protect and enhance the fish and wildlife resources at NSRR. Regular assessments are conducted to determine the status of these species.

- **Freeman and Quintero** (1990) report on 14 aerial surveys conducted along the coastline of NSRR and Vieques Island from **July 1988 to January 1989** and from **October 1989 and November 1989**. A Cessna 172 was used to fly surveys around Vieques Island, as well as around NSRR (but not the rest of Puerto Rico, according to the figure presented in the report). Only four of the aerial

Appendix A-2. Continued

surveys were flown in the vicinity of Vieques. These data were not available for inclusion in this report.

- **Diaz et al.** (1992) conducted aerial surveys around Puerto Rico and Vieques. Their report, however, does not provide clear information on when surveys were conducted. Diaz et al. mention monthly surveys **March through June 1981** and sporadically from **1988 to 1992**. Specific objectives were to (1) quantify possible biases leading to the development of a standardized aerial survey methodology to assess manatee abundance in Ceiba and Vieques Island; (2) study and characterize traditional manatee habitat to determine the different parameters that may contribute to the high incidence of manatees in Pelican Cove and a southeastern portion of Ensenada Honda; (3) determine manatee movements within and around Ceiba and Vieques Island; and (4) develop educational materials that would increase public awareness of manatees in the area. Aerial surveys covered the area from Punta Lima, Naguabo to Rio Fajardo in Fajardo, with concentrated survey effort at NSRR. Transects were also conducted on the northwest side of Vieques Island. These data were not available for inclusion in this report.

- **Department of the Navy/Geo-Marine, Inc.**

  - Aerial Survey of Marine Mammals and Sea Turtles in the Waters of the Virgin Passage, Caribbean Sea. The Navy contracted GMI in **2000** to conduct an aerial survey for the presence of marine mammals and sea turtles in the waters of the Virgin Passage. The purpose of the surveys was to: (1) clear the Virgin Passage before the ships commenced movement through the passage; (2) notify the ship point-of-contact and air support of any species sighted 1.5 nautical miles (NM) in front of the ship or within the surrounding waters of Culebra, Culebrita, and St. Thomas; and (3) observe and report to ship and air support any change in behavior of sea turtles and manatees or other marine mammals potentially affected within the Virgin Passage or surrounding waters during Navy training maneuvers. The survey area was comprised of 360 NM; north to south transects were flown 1.5 NM apart, with the flight transacts flown east to west between 1.0 and 1.5 NM apart in front of the ships and submarines. Aerial surveys were conducted 8 hours each day for 12 days prior to the commencement of the training maneuver and up to 8 hours after the completion of the exercise, with an additional 8-hour aerial survey the following day.

  - Fixed, high-wing aircraft aerial surveys were conducted over the surrounding waters of Vieques Island for manatees and other marine mammals, and sea turtles from **September 2000 through December 2001** (DoN 2001). Surveys were designed to cover likely manatee habitat around Vieques Island out to 1.5 to 2.0 NM. The initial survey transect line began on the north side of Vieques 0.25 NM off the northwest coast (Punta Arenas) and moved eastward to Punta Este. Rounding the eastern tip of Punta Este, the southern portion of the initial survey transect line moved west, 0.25 NM off the coast, toward Punta Boca Quebrada. The second survey transect began on the south side of Vieques, southwest of Punta Boca Quebrada between 1.5 and 2.0 NM offshore and moved east toward Punta Este. Rounding the eastern tip of Punta Este, the northern transect line moved west toward Punta Arenas. Areas covered included all of the coastal areas around the Island except the area between Punta Arenas and Punta Boca Quebrada located on the western end of Vieques. The survey efforts include the seagrass beds, fresh water and other areas manatees are known to frequent around the island. Aerial survey transects also included the surrounding waters of the Live Impact Area and the Eastern Maneuver Area. Surveys were conducted once weekly with three replicate surveys of 1.5 hours each morning, midday, and late afternoon.

  - Helicopter aerial surveys recorded sea turtle nests on Vieques three days per week during **January through December 2000**. The trackline was on the north side from the western

Appendix A-2. Continued

boundary of the civilian sector to around the south, east, and north side of Vieques to the western boundary of the Eastern Maneuver Area. Observed marine mammals and swimming sea turtles were also recorded during the survey period at a minimum altitude of 750 ft.

- Helicopter and high-wing surveys were conducted to ensure protection of turtle nests during Navy training exercises on the nesting beaches and to ensure that no marine mammals or sea turtles were within 1,000 yards of the target used during training exercises. These aerial surveys began in **May 2000** and continue **through 2002**. During the Navy training activities, intensive aerial surveys for marine mammals, sea turtles, and sea turtle nests were conducted for up to 21 consecutive days during each activity. Up to three surveys were conducted each day, within the Inner Range. Additional reconnaissance surveys were conducted during planned breaks, greater than one hour, in training activity throughout the day. The presence of sea turtle nests/crawls, sea turtles, or marine mammals within the area at the conclusion of each aerial survey was reported to Navy personnel with the corresponding location of the species.

Mignucci-Giannoni Marine Mammal Sighting Dataset

A marine mammal sighting dataset for Puerto Rico and the Virgin Islands was compiled by and received from Dr. Antonio Mignucci-Giannoni, director of the Caribbean Stranding Network (CSN). Data were included from published and unpublished reports, papers, and surveys and the primary sources are listed here:

- Marine mammal studies in the Puerto Rico area were initiated by **D.S. Erdman**, who recorded and cataloged cetacean sightings and strandings, and to a lesser extent, manatees (e.g., Erdman 1970; Caldwell and Erdman 1973; Erdman et al. 1973). Information is available from approximately **1953 through the 1980s** (Mignucci-Giannoni 1989).

- In **November 1980**, **NMFS and the Virgin Islands Division of Fish and Wildlife** initiated a joint effort to collect sighting and stranding information on marine mammals in waters surrounding the USVI (Mignucci-Giannoni 1989; Jobsis et al. 2001). Sightings are opportunistic and are reported to this governmental agency by filling out whale sighting network forms or reporting sightings via marine radio. The CSN database contained sightings up **to 1988**. Data post-1988 was requested from Ms. Barbra Kojis, with the Department of Natural Resources but no response was received. It should be noted that there might be multiple reports (meaning multiple sighting locations) for the same individual whales (Jobsis personal communication).

- **ECOmap** conducted four aerial surveys using helicopters to document the presence of manatees, whales, dolphins, and sea turtles on Puerto Rico's southwest coast, specifically Guayanilla Bay and adjacent coasts (Mignucci-Giannoni et al. 2002). Surveys were conducted on **17 January 2001, 4 April 2001, 18 July 2001, 21 November 2001, 19 April 2002, and 19 July 2002** along the coastline and over the shelf break. EcoEléctrica funded this project. Protected marine species had been reported to use this area, but the extent of their use of the area had been previously unknown. All sightings were of manatees and of green and hawksbill sea turtles (Mignucci-Giannoni et al. 2002). Along the south coast, manatees were common in the Jobos Bay area between Guayama and Salinas (Mignucci-Giannoni et al. 2002). Most of the manatee sightings were provided in the database, sea turtle sightings and more recent (2002) manatee sightings had to be scanned in from the survey report.

- In 1980, **Juan Carlos Jiménez** created the Marine Mammal Research Foundation, which existed until 1985 (Mignucci-Giannoni 1989). His main goal was to create awareness of the presence of marine mammals and to determine the distribution and abundance of species in the area.

Appendix A-2. Continued

Opportunistic sightings were collected and boat and aerial surveys conducted (Jiménez 1983). It is not clear from his dissertation, however, during what period these surveys took place. The work of Mignucci-Giannoni was initiated under the foundation.

- From **April 1999 through January 2001**, systematic surveys for bottlenose dolphins were conducted on the southwest coast of Puerto Rico from Mayaguez Bay in the north to El Faro in the south (**Rodriguez-Ferrer** 2001). Transects ranged from 8.85 km to 31.38 km offshore.

- As noted by Mignucci-Giannoni (1989), dedicated humpback whale research in the Puerto Rico, USVI, and BVI began when **Howard Winn** conducted a series of surveys in the Caribbean, which occasionally included the banks off Puerto Rico, the USVI, and the BVI. The purpose of the surveys was to research the winter habitat and acoustics of this species. These surveys were conducted between **1969 and 1974** and documented a number of different cetacean species, including minke whales and toothed whales (e.g., Taruski and Winn 1976; Winn and Perkins 1976).

- **David Mattila** has conducted field expeditions to assess the use of shallow water banks by humpback whales for calving (Mignucci-Giannoni 1989; Center for Coastal Studies 2002). His studies have encompassed work in Puerto Rico (**1978-1984**), the Silver Bank (multi-organizational expedition in 1984), the Lesser Antilles (1985), Virgin Bank (**1985-1986**) (Mattila and Clapham 1989), and the northeast coast of the Dominican Republic (1987-1991).

- **Historical** sightings and catches of killer whales were recorded in logbooks and journals of American pelagic whalers. **Reeves and Mitchell** (1988) compiled this information, which includes one sighting record for the Caribbean.

- The CSN conducted a series of 17 aerial and boat surveys off Vieques Island between **December 1999 and June 2000** for the **Puerto Rico Legislature** to analyze the status of marine mammals and sea turtles surrounding Puerto Rico and Vieques Island (Mignucci-Giannoni et al. 2000). The manatee and four cetacean species (bottlenose dolphin, Atlantic spotted dolphin, short-finned pilot whale, and humpback whale) as well as green and leatherback sea turtles were sighted. Strandings, including Cuvier's beaked whales, were documented. While marine mammal sightings were provided as part of this database, the sea turtle data had to be requested separately from Dr. Antonio Mignucci-Giannoni and is included in this report.

- The **Years of the North Atlantic Humpback** (**YoNAH**) project is an international collaboration to study North Atlantic humpback whales across most of their known range (e.g., Smith et al. 1999). It was conceived to address large-scale issues, such as the size and structure of the population, vital rates, migratory movement, and the structure of the mating system. The project involved two intensive years of field research. During the summers of **1992 and 1993**, intensive photographic and genetic sampling was performed concurrently in five high-latitude feeding grounds: the Gulf of Maine (U.S.), Canada, Greenland, Iceland, and Norway. During the winter months, fieldwork was performed in the West Indies, a shared, low-latitude breeding ground. The Puerto Rico expedition was conducted off Punta Aqujereada on Borinquen Bank and off Punta Higuero where humpback whale concentrations had been conducted (Mignucci-Giannoni et al. 1992). There was also one dedicated cruise to Mona Island in the Mona Passage. Sightings of other cetaceans were also noted. Sampling techniques were standardized within and between areas to ensure data comparability and to minimize sampling bias. A central archive was established for all photographs, tissue samples, and data to facilitate analysis and to provide a valuable legacy for future investigators.

- **Alsina-Guerrero et al.** (2001) reported on marine mammal sightings made during boat-based surveys in San Juan Bay. From **1999 to 2001**, only six sightings were documented: two bottlenose dolphins and four manatees.

Appendix A-2. Continued

- **Seafarers Expedition** in **1986** began whale-watching expeditions in Tortola, BVI (Marion 1987). The trips were timed to coincide with the peak of the humpback whale mating and calving season.

- The **San Juan Bay Estuarine Program** received sighting reports from dredging operations (ECOES is the company) in the area and forwarded them to CSN (Mignucci-Giannoni personal communication). Only marine mammals were sighted (Mignucci-Giannoni personal communication).

- **Perrin et al.** (1987) provided a revision of the spotted dolphins. In this revision, all known records for which photos or specimens were re-examined, including those for the Caribbean. Mignucci-Giannoni (1989) probably used this publication to correct identifications made prior to that date of spotted dolphins in the area.

Radio Tracking Studies

In May 1993, through a Memorandum of Understanding with the Navy, the U.S. Geological Survey initiated the **Sirenia Project** radio-tracking studies of manatees in eastern Puerto Rico (Reid 1994). A capture operation was undertaken in May 1993 and a total of five manatees were captured at NSRR; three were released with satellite tags. Eventually, a total of eight manatees were tracked from **1992 through 1996** (Reid 1994, 1995, 1996, 1997). Usage by manatees of waters around NSRR and the northwest coast of Vieques was determined and also significant usage of areas along the southern shore of Vieques (previously thought to be unsuitable manatee habitat) (Lefebvre et al. 2000). Consistent with previous aerial surveys, satellite-tracked manatees extensively used the seagrass beds along the northwest coast of Vieques and the areas near NSRR (Reid and Kruer 1998). Most individuals remained near, or frequently returned to the waters of NSRR; however, one individual swam 50 km south to Puerto Patillas and another individual ranged 40 km north to Luquillo (Lefebvre et al. 2001).

From **1997 to 2000**, the Sirenia Project collaborated with the USFWS Caribbean Field Office and the Caribbean Stranding Network to radio-tag four manatees in western Puerto Rico. Manatees were captured at the Río Guanajibo near Mayaguez, and primarily used the waters from Mayaguez south to Boquerón (Mignucci-Giannoni et al. 1999a; Lefebvre et al. 2001). One manatee traveled 210 km north and east along the coast to just east of San Juan, where he remained for several weeks before returning to the Río Guanajibo (Mignucci-Giannoni et al. 1999a).

Stranding Data

Marine mammal stranding networks are under the jurisdiction of NMFS and are nominally based on the administrative regions of the NMFS (Geraci and Lounsbury 1993). Wilkinson and Worthy (1999) discuss the genesis of marine mammal stranding networks in the U.S. Legal authority for the U.S. stranding response network is contained in the MMPA. In the Marine Mammal Health and Stranding Response Act (in the 1992 Amendments to the MMPA), Congress made it national policy to monitor the various factors affecting the health of marine mammal populations (Becker et al. 1994). Collection and studies of stranded marine mammals have contributed much to what is known about each species. To respond to strandings, volunteer stranding networks were established in all coastal states, which are part of the Southeast Marine Mammal Stranding Network (SEMMSN). The NMFS is responsible for cetaceans and all pinnipeds in the vicinity of the PROA/St. Croix OPAREA, while manatees are under the jurisdiction of the USFWS.

- The **Caribbean Stranding Network (CSN)** was created in October 1989 under the jurisdiction of the SEMMSN but has some degree of autonomy in order to function effectively as part of a “greater Caribbean network” (Mignucci-Giannoni 1996; Mignucci-Giannoni et al. 1999b). The CSN maintains stranding data collected by the Puerto Rico DNER, the USVI Department of Planning and Natural

Appendix A-2. Continued

Resources (DPNR), and the BVI Conservation and Fisheries Department. Dr. Antonio Mignucci-Giannoni, head of the CSN, compiled the marine mammal stranding data used in this MRA. Some incidental fisheries bycatch data were found within the stranding database and extracted. Most of the stranding records are from Puerto Rico, the USVI, and the BVI; however, stranding records for 24 Caribbean countries are also included. The earliest historical stranding in the CSN database dates from **1867 and the latest from 2002.**

- Dr. Antonio Mignucci-Giannoni compiled the sea turtle stranding data for Puerto Rico and the USVI used in this MRA report. Included in the sea turtle database are 315 stranding records from **1985 to 2000**, although the majority of these records fall between the years of 1990 and 1996, due to the creation of CSN in late 1989 (Pinto-Rodríguez et al. 1995) and analysis of this data by Ortiz Rivera (2000). The database contains stranding records of five sea turtle species for Puerto Rico and the USVI. Each stranding record details the species, the date and location of the stranding, the predominant cause of death, the sex, the length, and the condition of the animal. Details on how sea turtle stranding networks function are found in Shaver and Teas (1999). Access to the complete post-1995 stranding data (not available electronically) was requested from the Puerto Rico DNER Secretary, but no response was received.

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APPENDIX B: MARINE MAMMALS

Table

The winter distribution of marine mammal occurrence records in the PROA/St. Croix OPAREA by surface grid block B-1
The spring distribution of marine mammal occurrence records in the PROA/St. Croix OPAREA by surface grid block B-2
The summer distribution of marine mammal occurrence records in the PROA/St. Croix OPAREA by surface grid block B-3
The fall distribution of marine mammal occurrence records in the PROA/St. Croix OPAREA by surface grid block B-4

Figure

Occurrence of all marine mammals in the PROA/St. Croix OPAREA and vicinity B-1
Occurrence of endangered marine mammals and unidentified rorquals in the PROA/St Croix OPAREA and vicinity B-2
Occurrence of the humpback whale in the PROA/St. Croix OPAREA and vicinity B-3
Occurrence of the fin whale in the PROA/St. Croix OPAREA and vicinity B-4
Occurrence of unidentified rorquals in the PROA/St. Croix OPAREA and vicinity B-5
Occurrence of the blue whale in the PROA/St. Croix OPAREA and vicinity B-6
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Occurrence of the minke whale in the PROA/St. Croix OPAREA and vicinity B-9
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Occurrence of beaked whales in the PROA/St. Croix OPAREA and vicinity B-12
Occurrence of the rough-toothed dolphin in the PROA/St. Croix OPAREA and vicinity B-13
Occurrence of the bottlenose dolphin in the PROA/St. Croix OPAREA and vicinity B-14
Occurrence of the pantropical spotted dolphin in the PROA/St. Croix OPAREA and vicinity B-15
Occurrence of the Atlantic spotted dolphin in the PROA/St. Croix OPAREA and vicinity B-16
Occurrence of the spinner dolphin in the PROA/St. Croix OPAREA and vicinity B-17
Occurrence of the striped dolphin in the PROA/St. Croix OPAREA and vicinity B-18
Occurrence of the Clymene dolphin in the PROA/St. Croix OPAREA and vicinity B-19
Occurrence of common dolphins in the PROA/St. Croix OPAREA and vicinity B-20
Occurrence of the Fraser's dolphin in the PROA/St. Croix OPAREA and vicinity B-21
Occurrence of the Risso's dolphin in the PROA/St. Croix OPAREA and vicinity B-22
Occurrence of the melon-headed whale and pygmy killer whale in the PROA/St. Croix OPAREA and vicinity B-23
Occurrence of the false killer whale in the PROA/St. Croix OPAREA and vicinity B-24
Occurrence of the killer whale in the PROA/St. Croix OPAREA and vicinity B-25
Occurrence of pilot whales in the PROA/St. Croix OPAREA and vicinity B-26

Table B-1. The winter distribution of marine mammal occurrence records in the PROA/St. Croix OPAREA by surface grid block. Occurrence data are taken from available stranding and incidental fisheries bycatch as well as aerial and shipboard sighting survey records. The total number of records is presented with the total number of individual animals in parentheses. The data presented are not reflective of survey effort.

GRID BLOCK	COMMON NAME OF MARINE MAMMALS																	
	Atlantic Spotted Dolphin	Blainville's Beaked Whale	Bottlenose Dolphin	Common Dolphin	Cuvier's Beaked Whale	Humpback Whale	*Kogia* spp.	Minke Whale	Pantropical Spotted Dolphin	Pilot Whales	Rough-toothed Dolphin	Short-finned Pilot Whale	Sperm Whale	Spinner Dolphin	Unidentified Beaked Whale	Unidentified Cetacean	Unidentified Rorqual	West Indian Manatee
1D						2(3)						1(15)						
1K					1(3)	4(11)												
1L						1(1)										2(3)		
1M						1(4)												
2A				1(27)		2(2)							1(2)					
2B	1(54)		2(19)			7(11)										1(4)		
3A						1(2)								1(60)		1(1)		
3B														1(200)				
4	2(51)		12(93)			16(28)						2(10)		4(411)		3(8)		
5		1(2)	2(60)			5(9)	1(5)					1(8)	3(10)	1(30)	1(1)	1(1)		
6B	1(30)		1(4)			7(12)						2(32)	2(9)					
7													1(2)					
8	1(48)															1(1)		
10													1(4)					
12	1(25)											1(1)	2(8)	1(27)				
UTR (6A)							2(6)					1(6)	1(2)			1(2)		
W-369				1(1)		1(1)		1(3)				6(148)	1(7)			2(2)	1(1)	
W-370	2(42)																	
W-372	2(47)														1(1)			
W-373																1(3)		
W-374	1(37)												1(5)			1(2)		
W-378			1(3)			1(2)		1(3)	1(18)	2(17)	1(3)	3(22)	1(1)		1(1)	2(5)		
W-428			1(1)		1(1)							1(6)	1(1)			4(5)		2(2)
W-429						1(2)							1(1)					

Table B-2. The spring distribution of marine mammal occurrence records in the PROA/St. Croix OPAREA by surface grid block. Occurrence data are taken from available stranding and incidental fisheries bycatch as well as aerial and shipboard sighting survey records. The total number of records is presented with the total number of individual animals in parentheses. The data presented are not reflective of survey effort.

GRID BLOCK	COMMON NAME OF MARINE MAMMALS								
	Bottlenose Dolphin	Humpback Whale	Killer Whale	*Kogia* spp.	Short-finned Pilot Whale	Sperm Whale	Spinner Dolphin	Unidentified Cetacean	West Indian Manatee
1M					1(100)				
2B	2(18)	1(6)			1(12)	1(1)			
4	2(1007)						1(75)		
5	4(46)	1(6)	1(3)		1(1)				
6B	1(1)				2(9)	1(1)	1(50)		
7								1(1)	
12					2(6)	1(2)			
UTR (11)							1(85)		
UTR (6A)					1(38)	2(3)			
W-369					2(51)				
W-370								1(8)	
W-373						1(1)			
W-378				1(1)					
W-428	1(35)								7(8)

Table B-3. The summer distribution of marine mammal occurrence records in the PROA/St. Croix OPAREA by surface grid block. Occurrence data are taken from available stranding and incidental fisheries bycatch as well as aerial and shipboard sighting survey records. The total number of records is presented with the total number of individual animals in parentheses. The data presented are not reflective of survey effort.

Grid Block	Common Name Of Marine Mammals										
	Atlantic Spotted Dolphin	Bottlenose Dolphin	Cuvier's Beaked Whale	False Killer Whale	Killer Whale	Risso's Dolphin	Short-finned Pilot Whale	Sperm Whale	*Stenella* spp.	Unidentified Cetacean	West Indian Manatee
1F					1(8)						
2B		1(3)									
3A							1(4)				
4	3(71)			1(50)			2(89)	1(3)			2(2)
5							1(20)				
6B							1(1)		1(3)		
W-369						1(19)	1(2)				
W-428		1(1)	1(1)					1(3)		6(16)	12(12)

Table B-4. The fall distribution of marine mammal occurrence records in the PROA/St. Croix OPAREA by surface grid block. Occurrence data are taken from available stranding and incidental fisheries bycatch as well as aerial and shipboard sighting survey records. The total number of records is presented with the total number of individual animals in parentheses. The data presented are not reflective of survey effort.

GRID BLOCK	COMMON NAME OF MARINE MAMMALS								
	Bottlenose Dolphin	Humpback Whale	Killer Whale	Short-finned Pilot Whale	Sperm Whale	Spinner Dolphin	Unidentified Beaked Whale	Unidentified Cetacean	West Indian Manatee
1F			1(1)						
1G					1(5)				
1K	1(1)								
1L								1(1)	
2B		1(1)			1(1)				
3A						1(3)			
4	3(17)				1(2)	1(7)			
5				1(3)					
6B				1(15)	1(1)	1(200)			
UTR (6A)	1(45)			1(45)			1(2)		
W-369	1(17)			1(2)	2(8)				
W-428	1(1)				1(2)			1(1)	14(27)

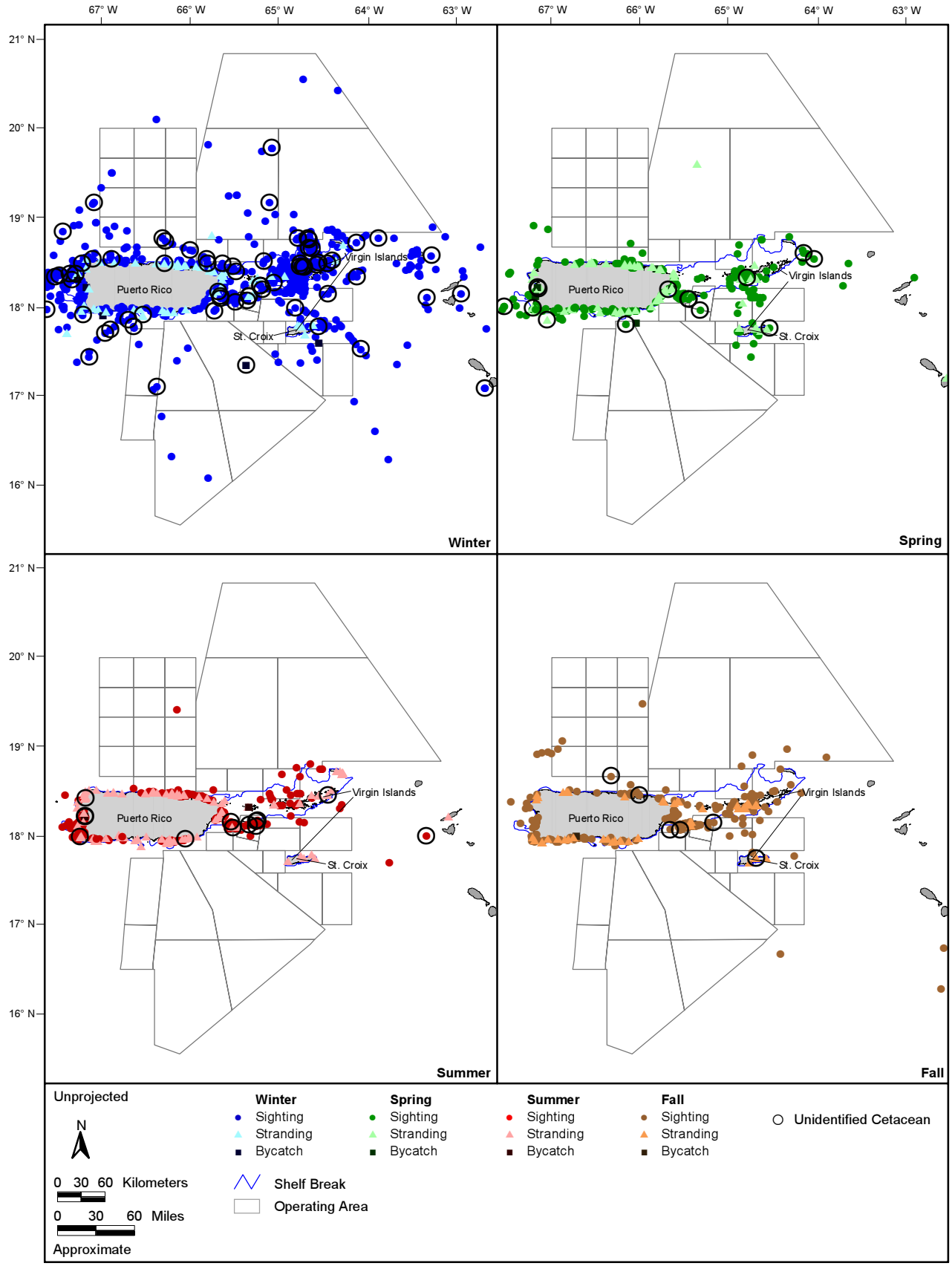


Figure B-1. Occurrence of all marine mammals in the PROA/St. Croix OPAREA and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

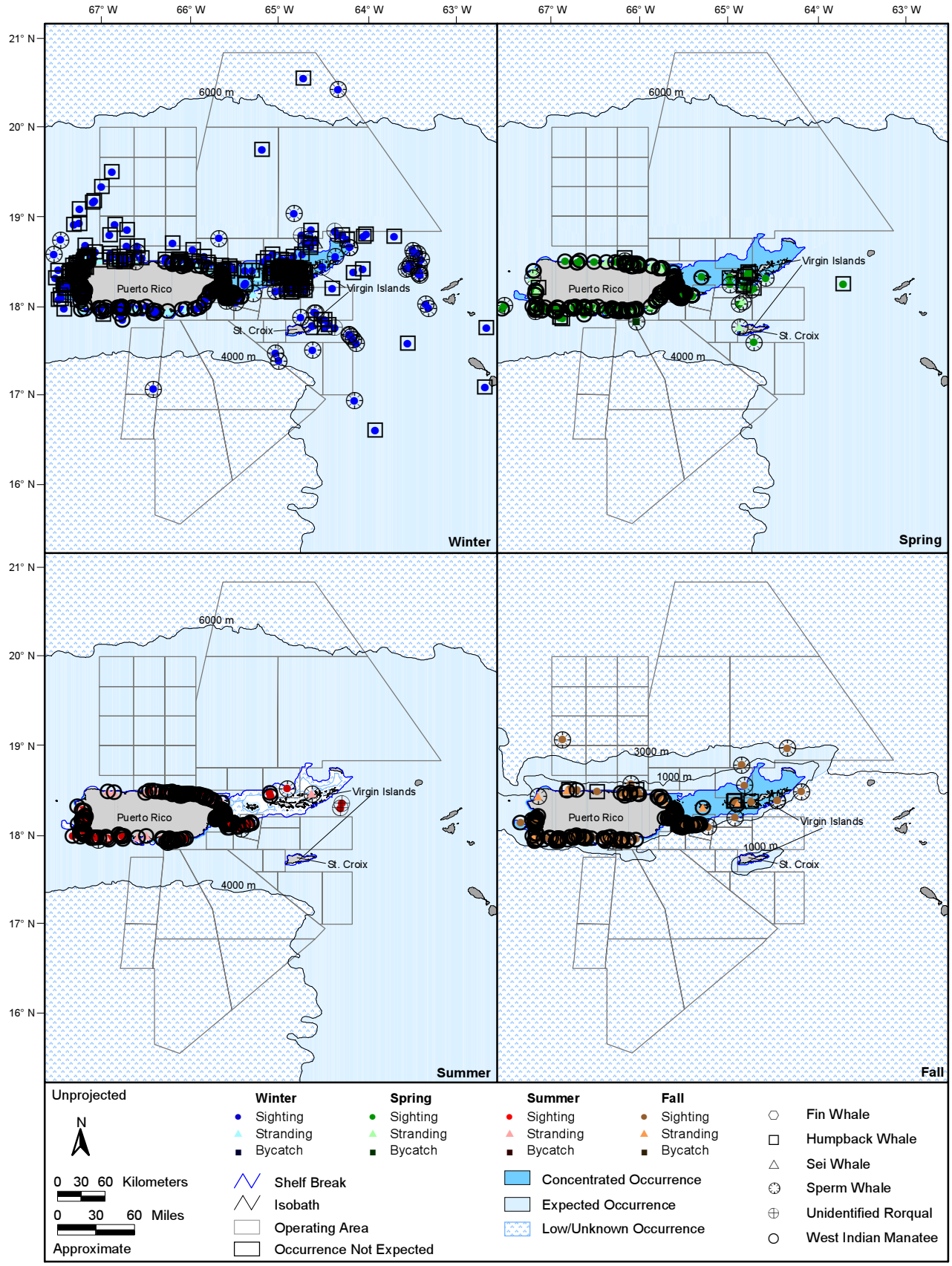


Figure B-2. Occurrence of endangered cetaceans and unidentified rorquals in the PROA/St. Croix OPAREA and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

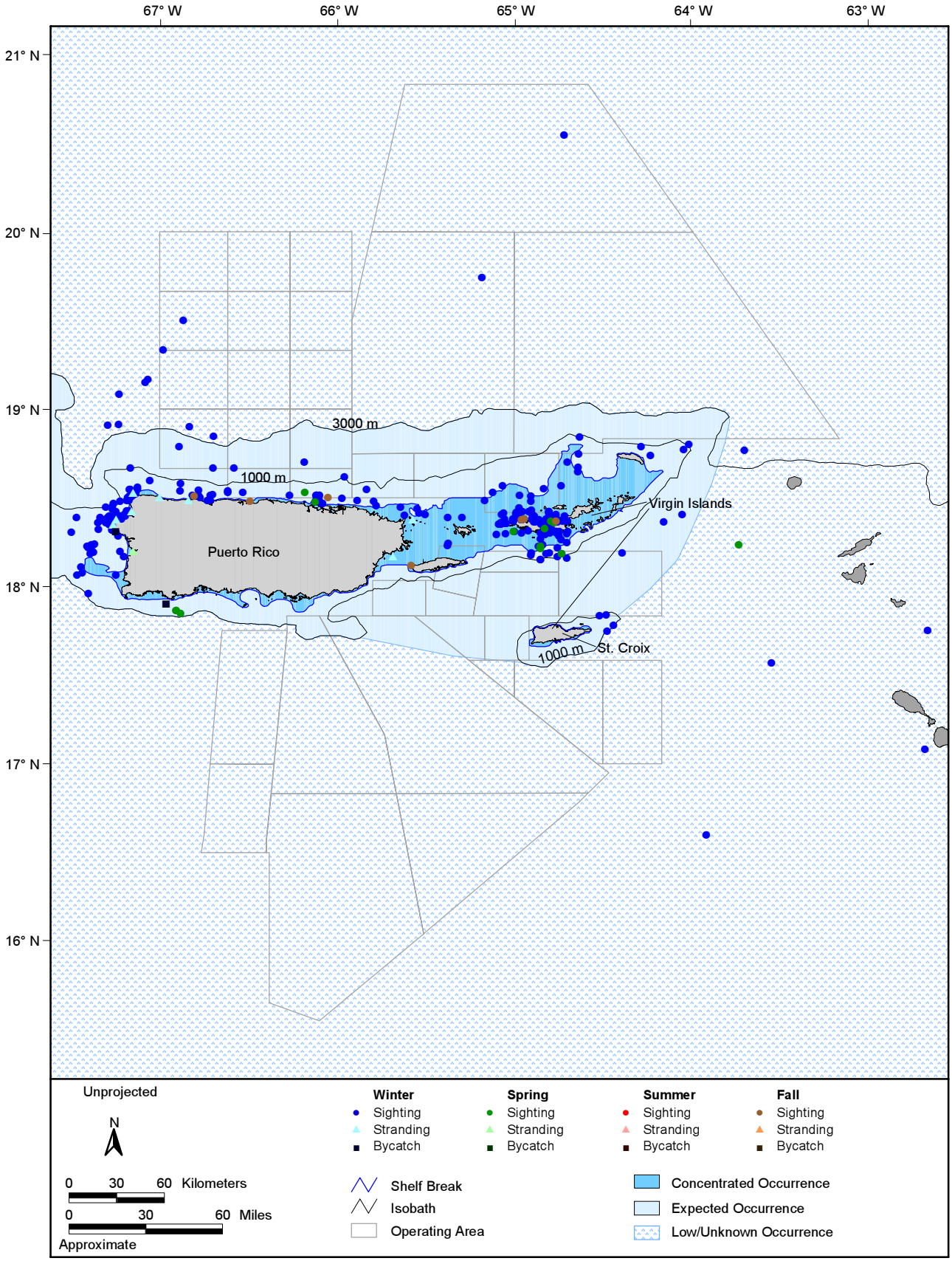


Figure B-3. Occurrence of the humpback whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons except summer when this species is not expected in this area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

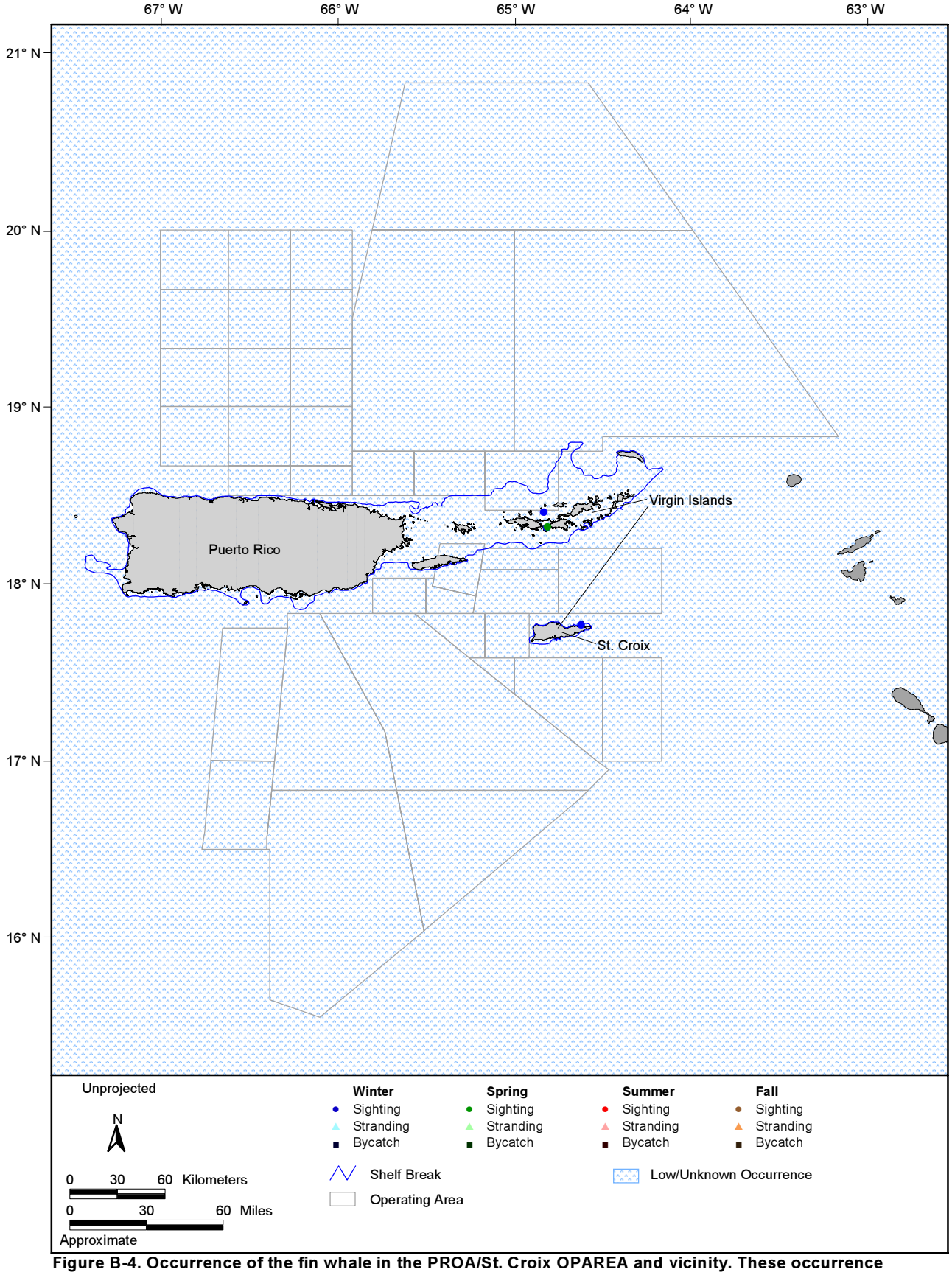


Figure B-4. Occurrence of the fin whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons except summer when this species is not expected in this area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

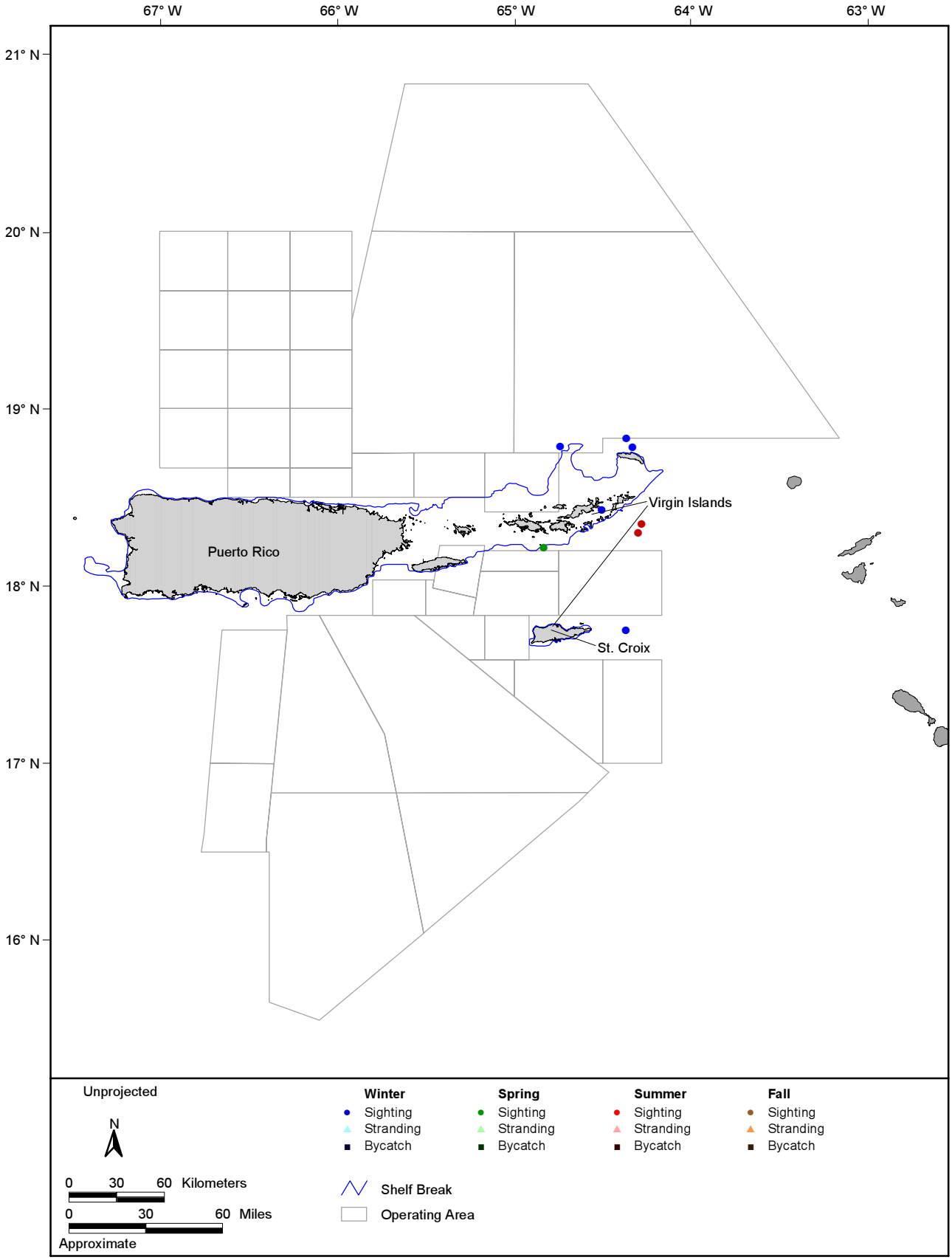


Figure B-5. Occurrence of unidentified rorquals in the PROA/St. Croix OPAREA and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

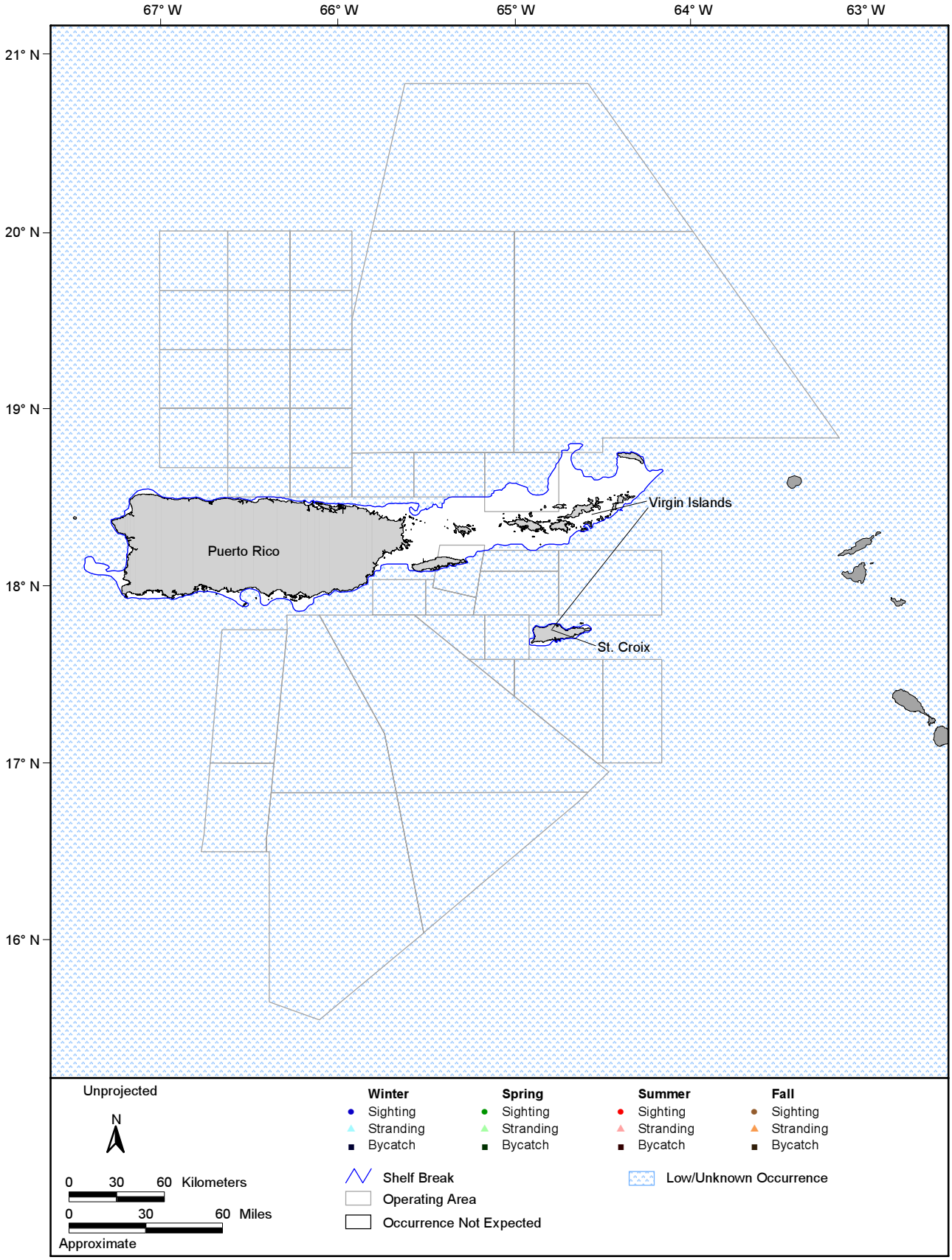


Figure B-6. Occurrence of the blue whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

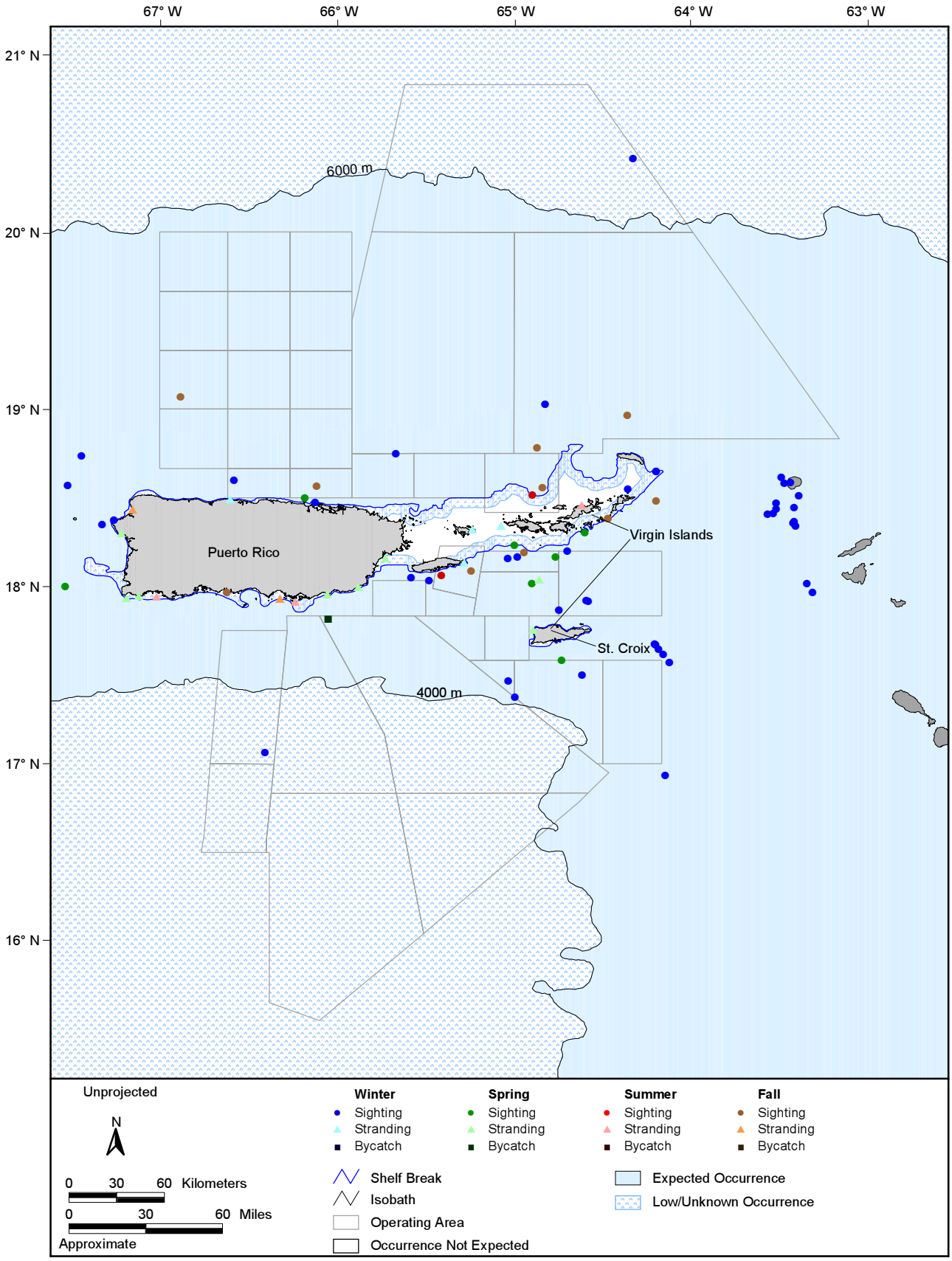


Figure B-7. Occurrence of the sperm whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

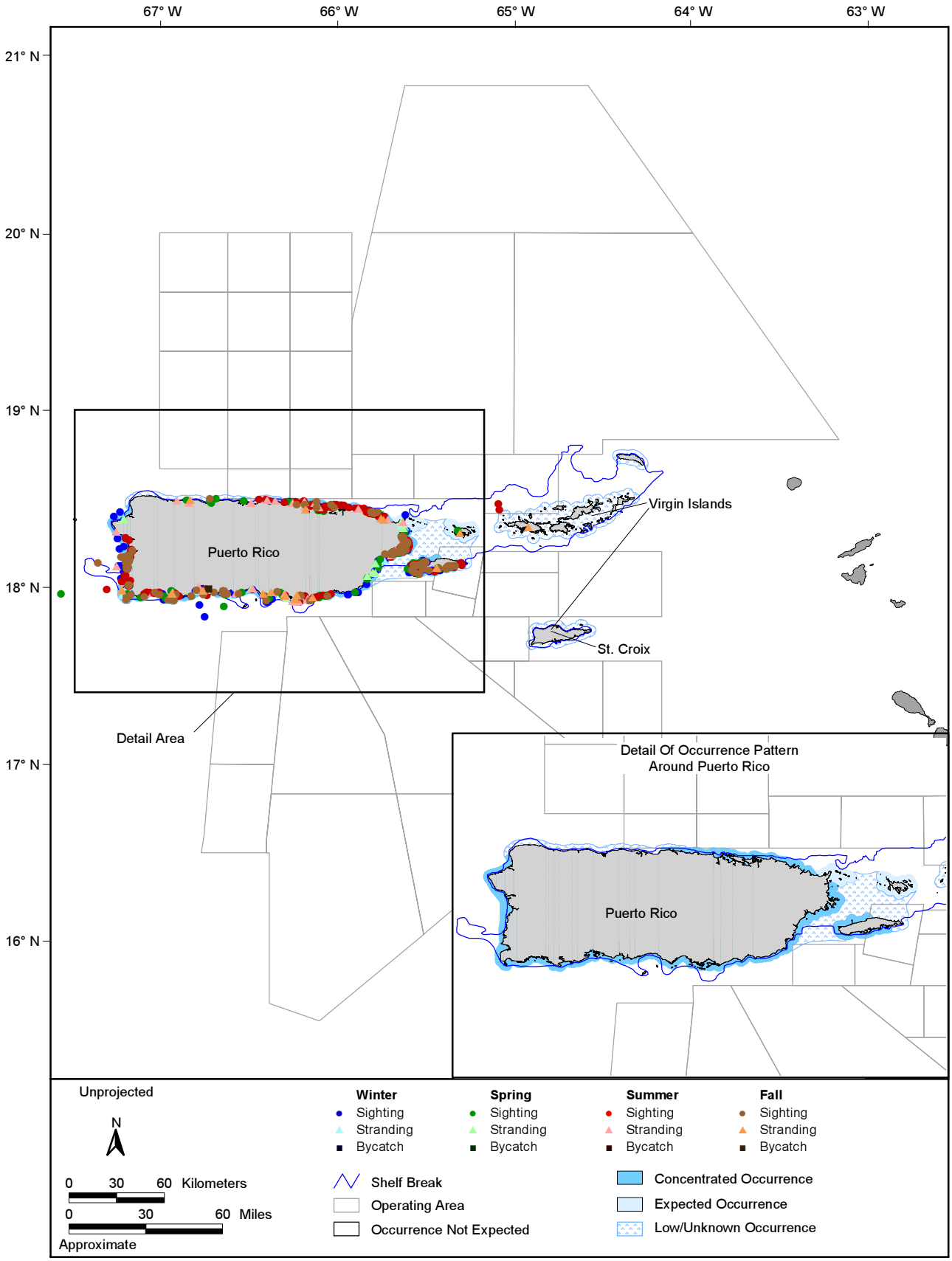


Figure B-8. Occurrence of the West Indian manatee in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

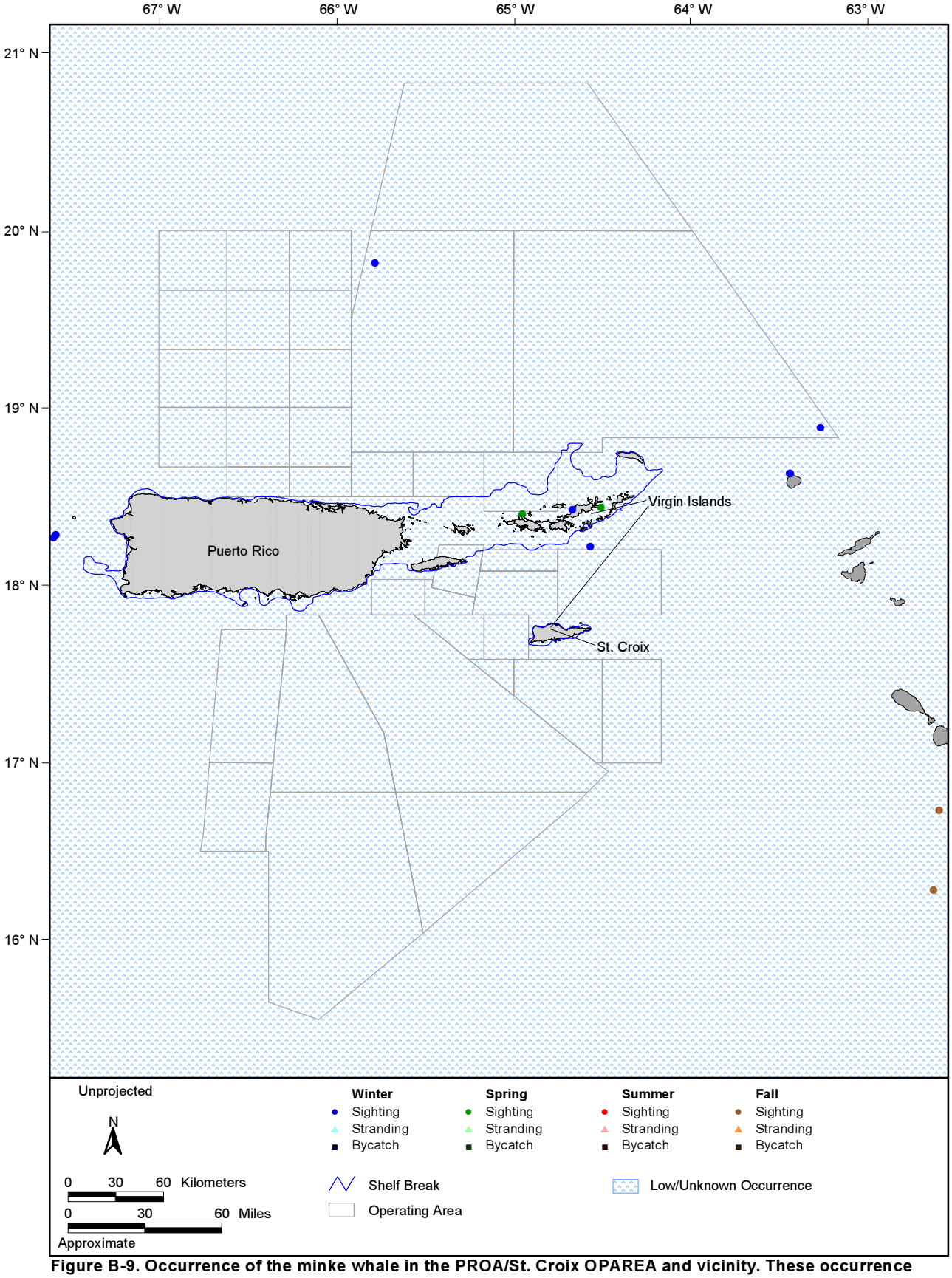


Figure B-9. Occurrence of the minke whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons except summer when this species is not expected in this area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

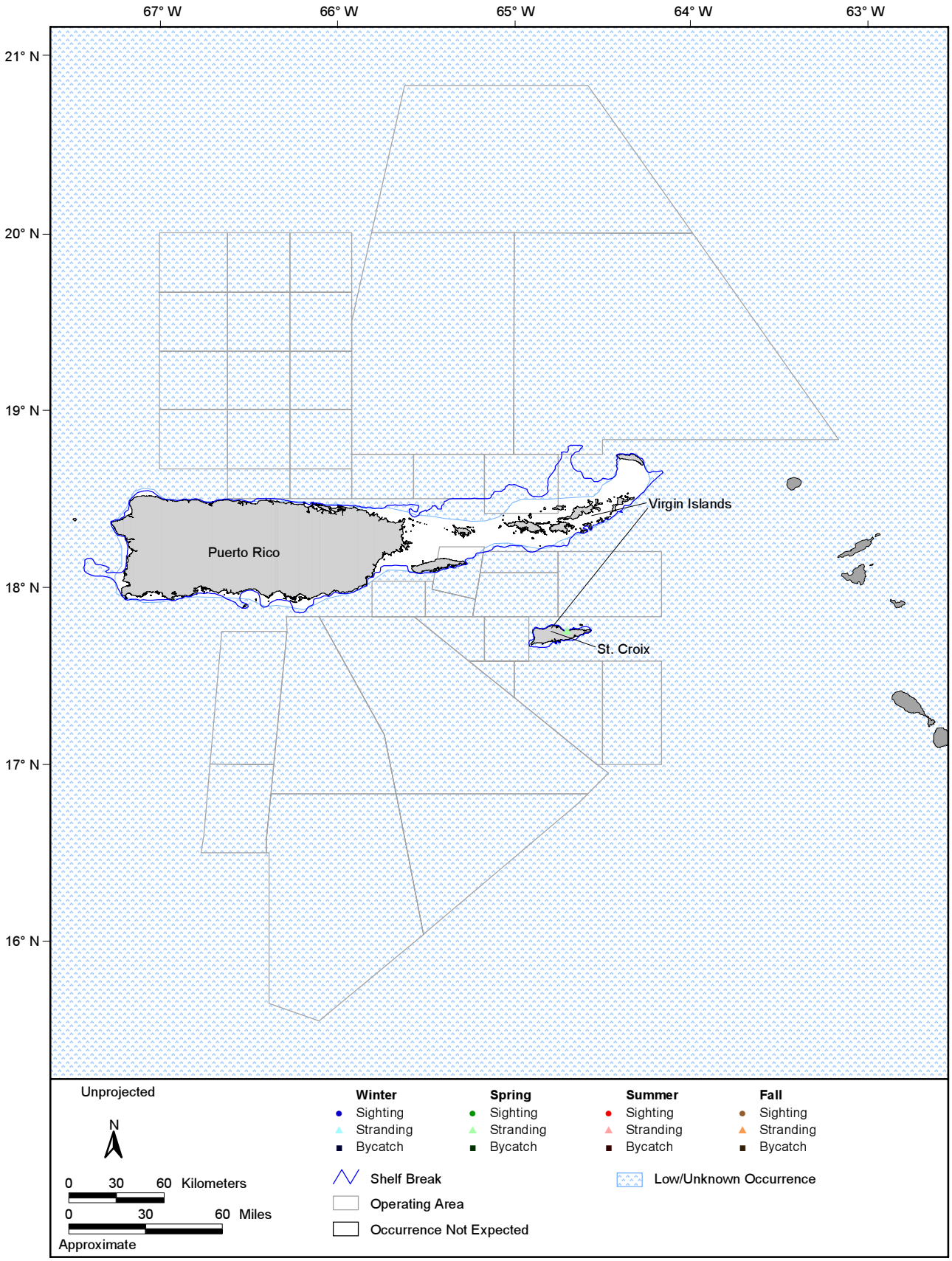


Figure B-10. Occurrence of the Bryde's whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

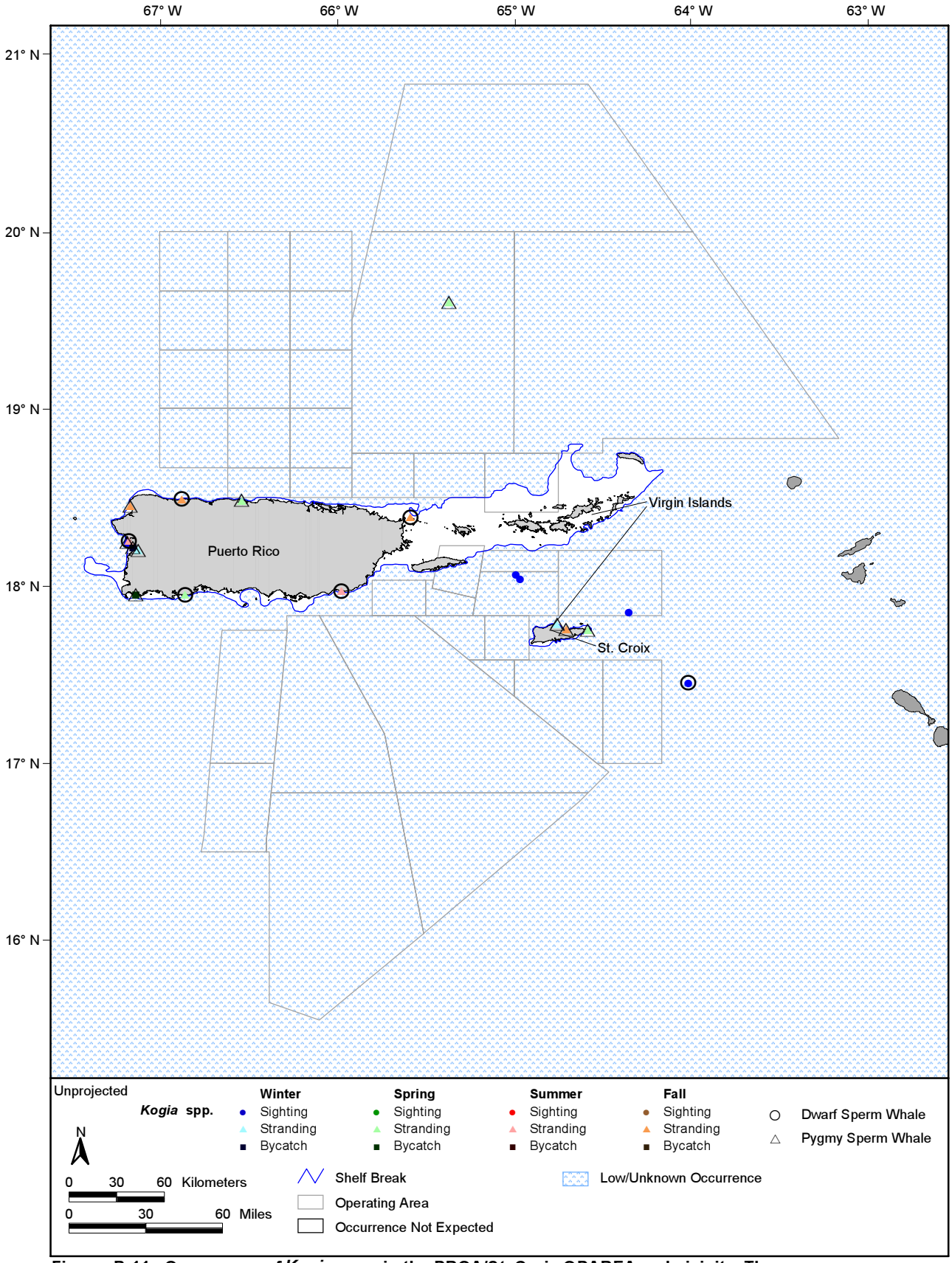


Figure B-11. Occurrence of *Kogia* spp. in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

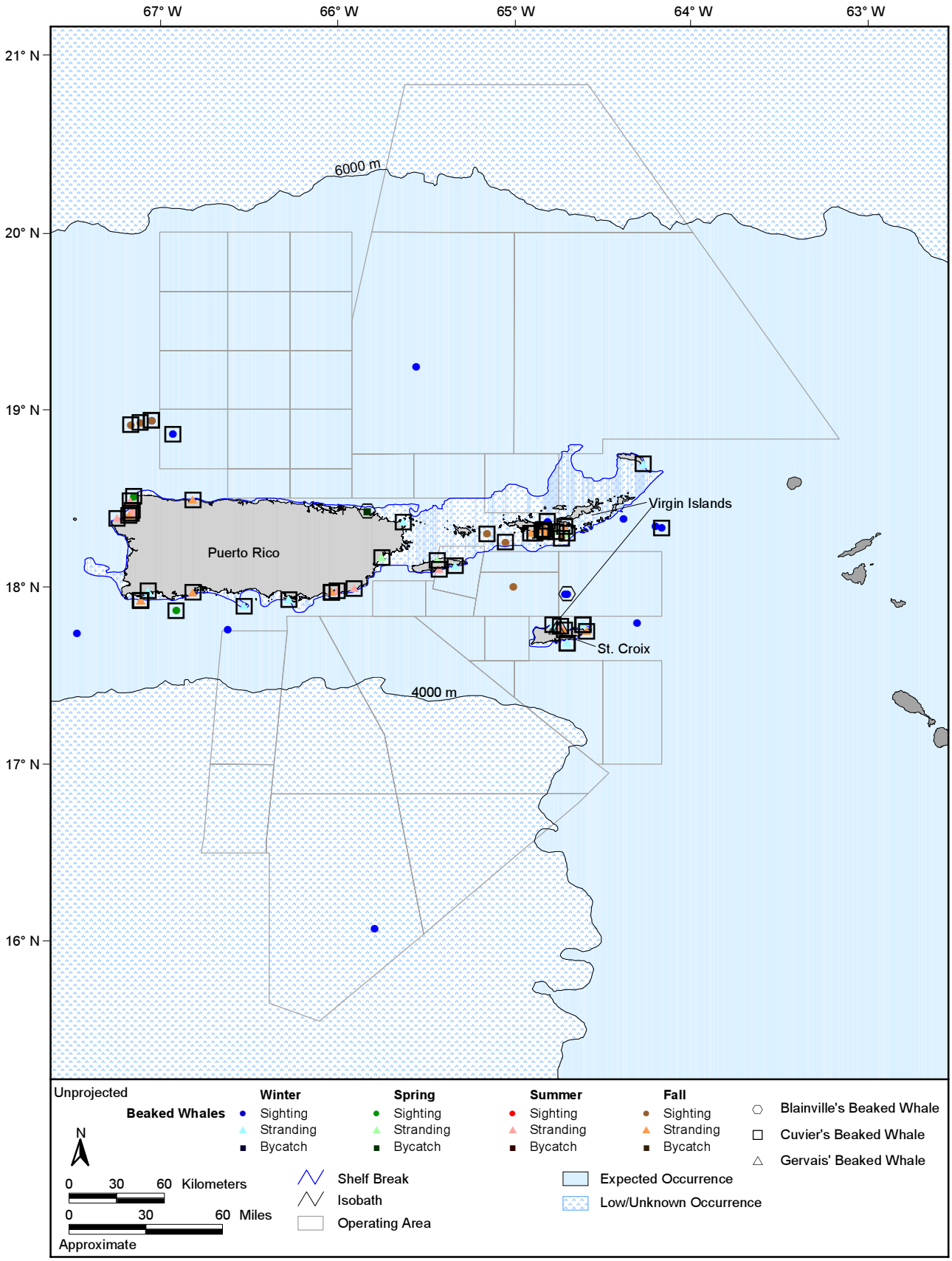


Figure B-12. Occurrence of beaked whales in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

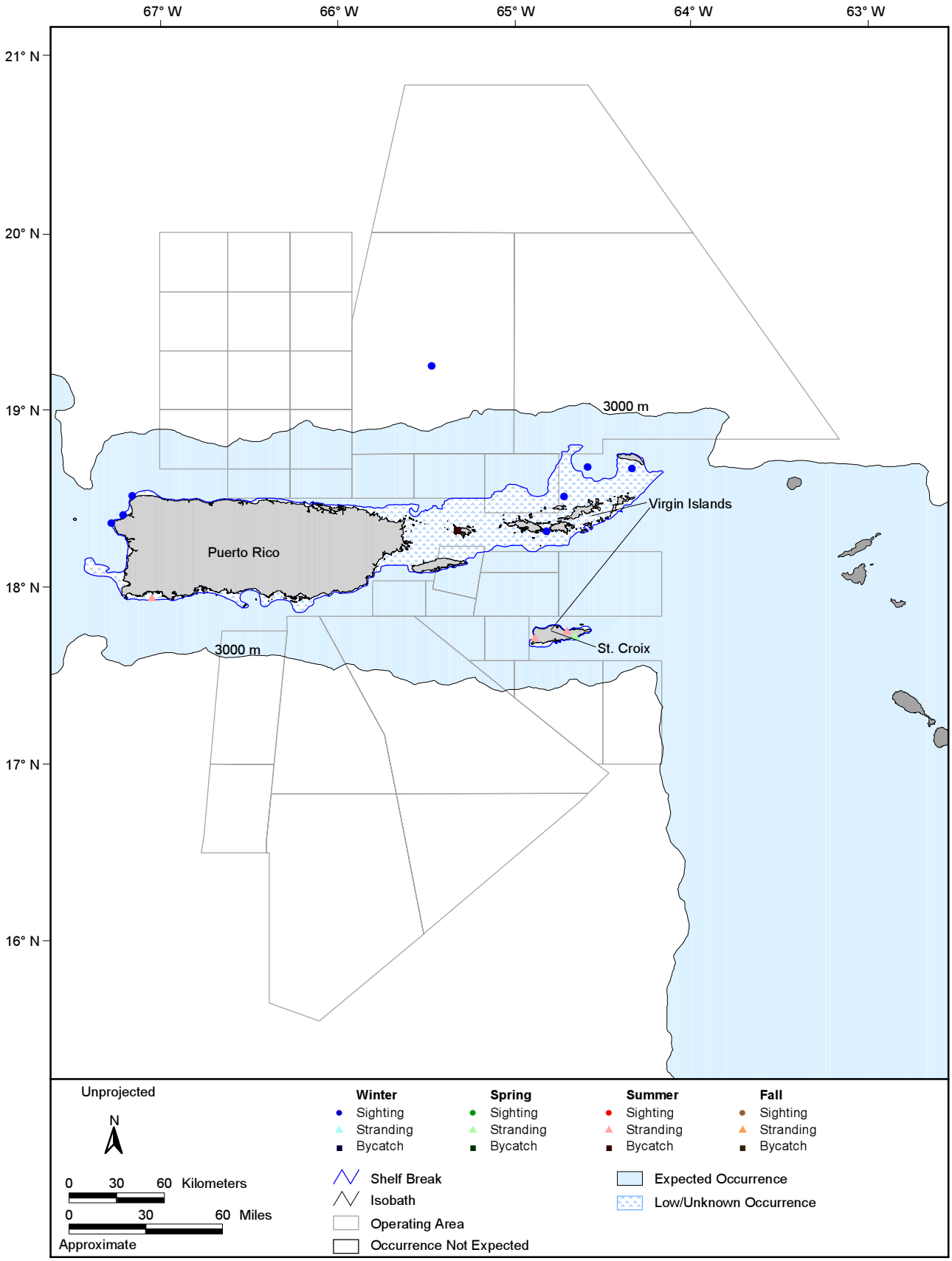


Figure B-13. Occurrence of the rough-toothed dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

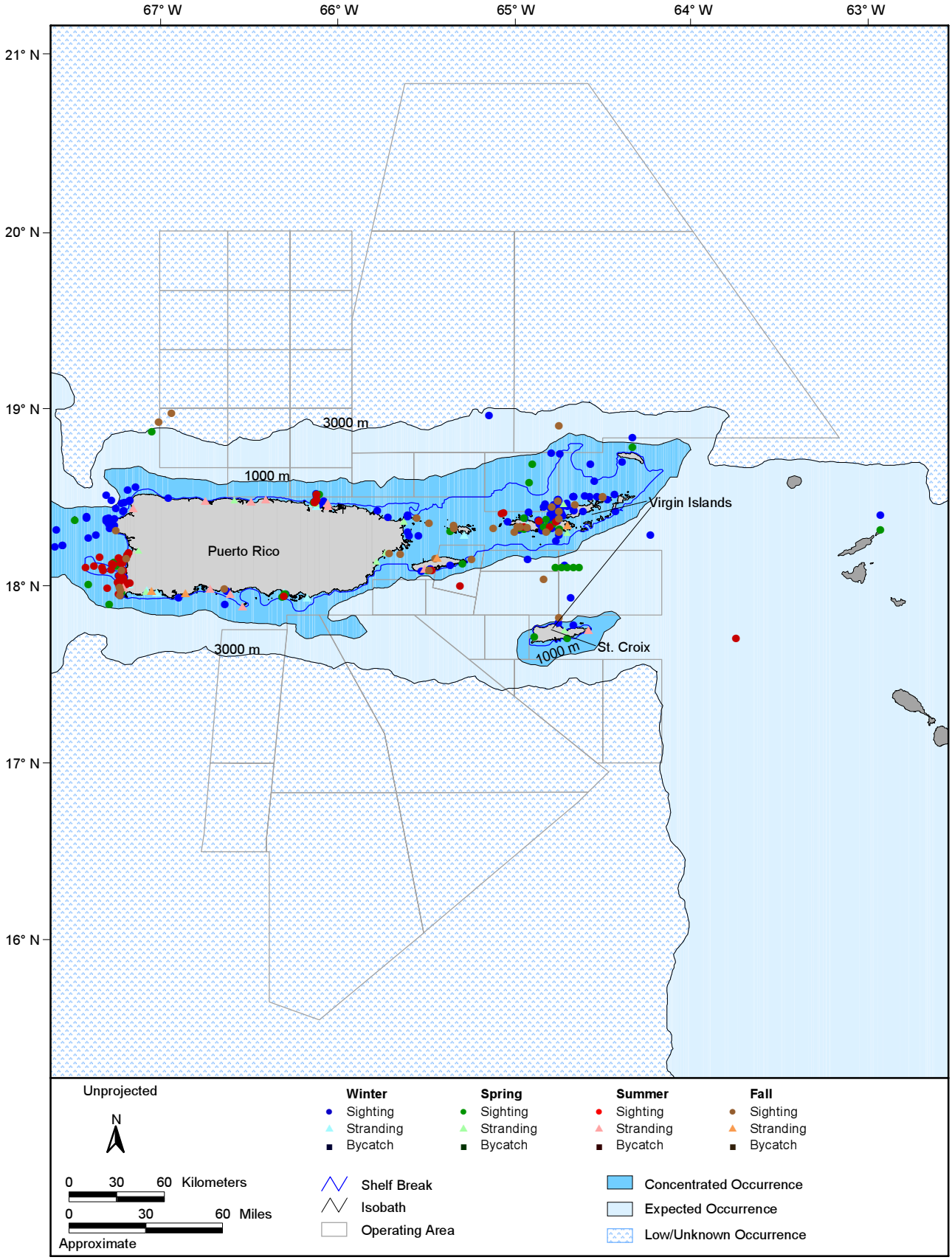


Figure B-14. Occurrence of the bottlenose dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

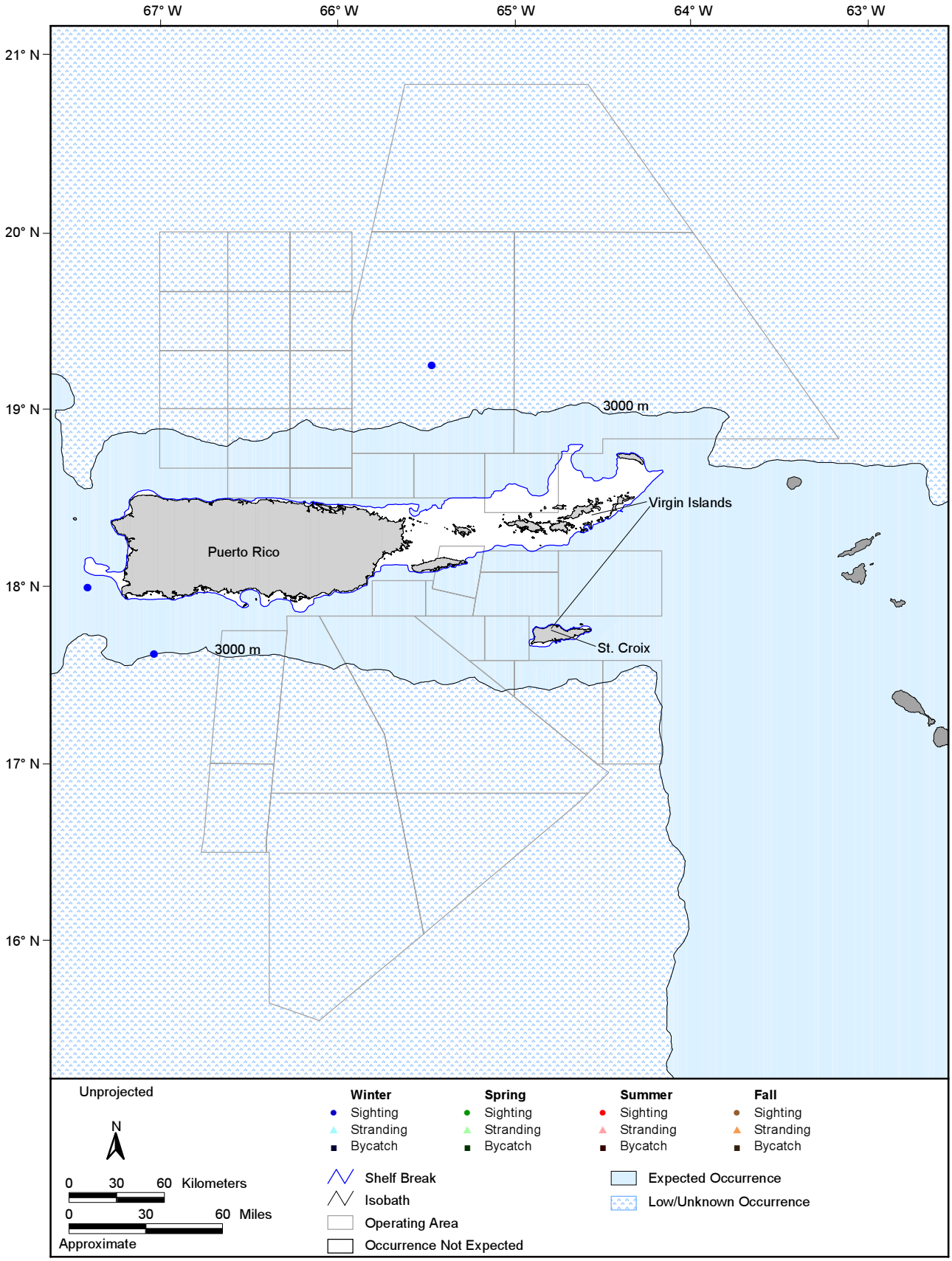


Figure B-15. Occurrence of the pantropical spotted dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

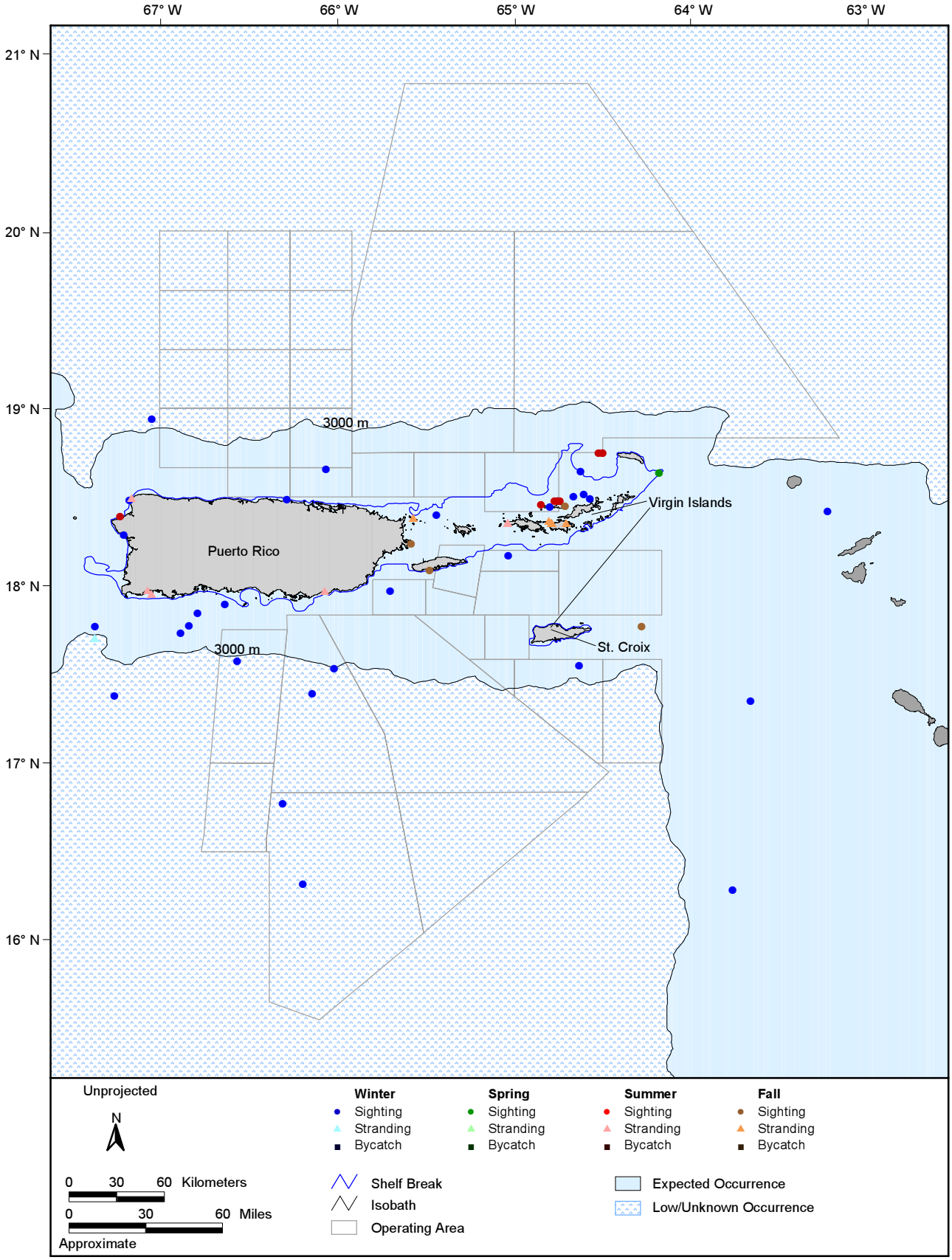


Figure B-16. Occurrence of the Atlantic spotted dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

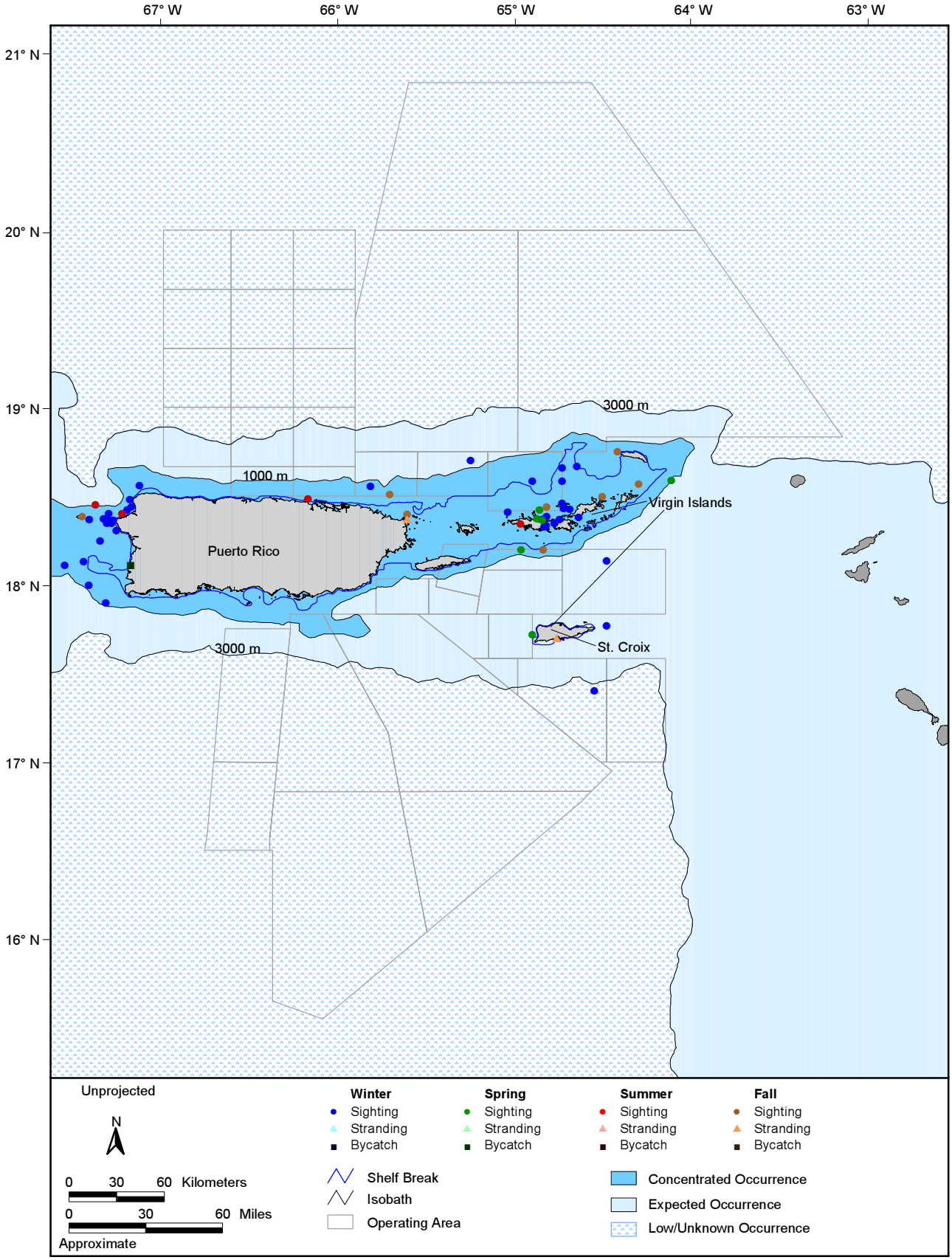


Figure B-17. Occurrence of the spinner dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

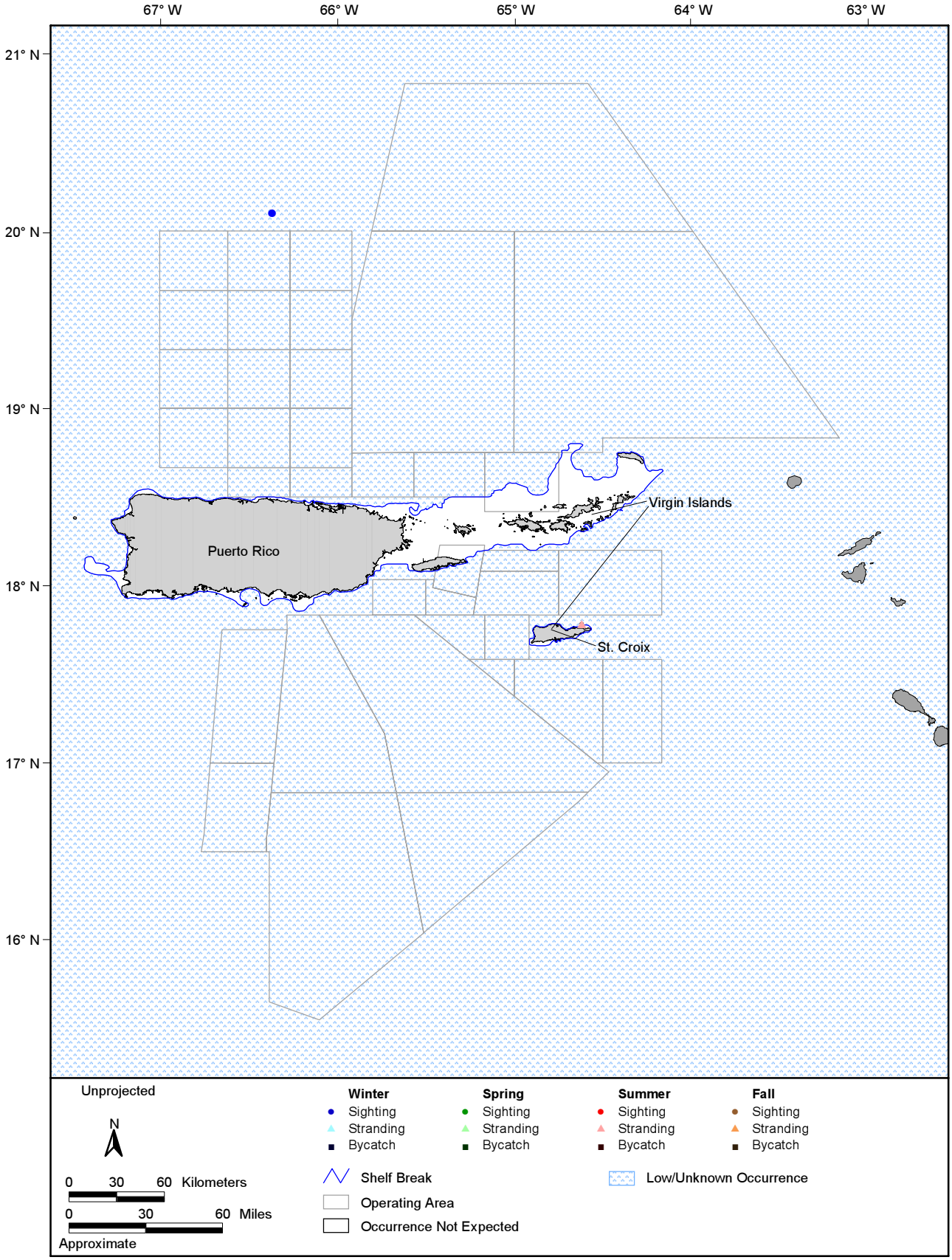


Figure B-18. Occurrence of the striped dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

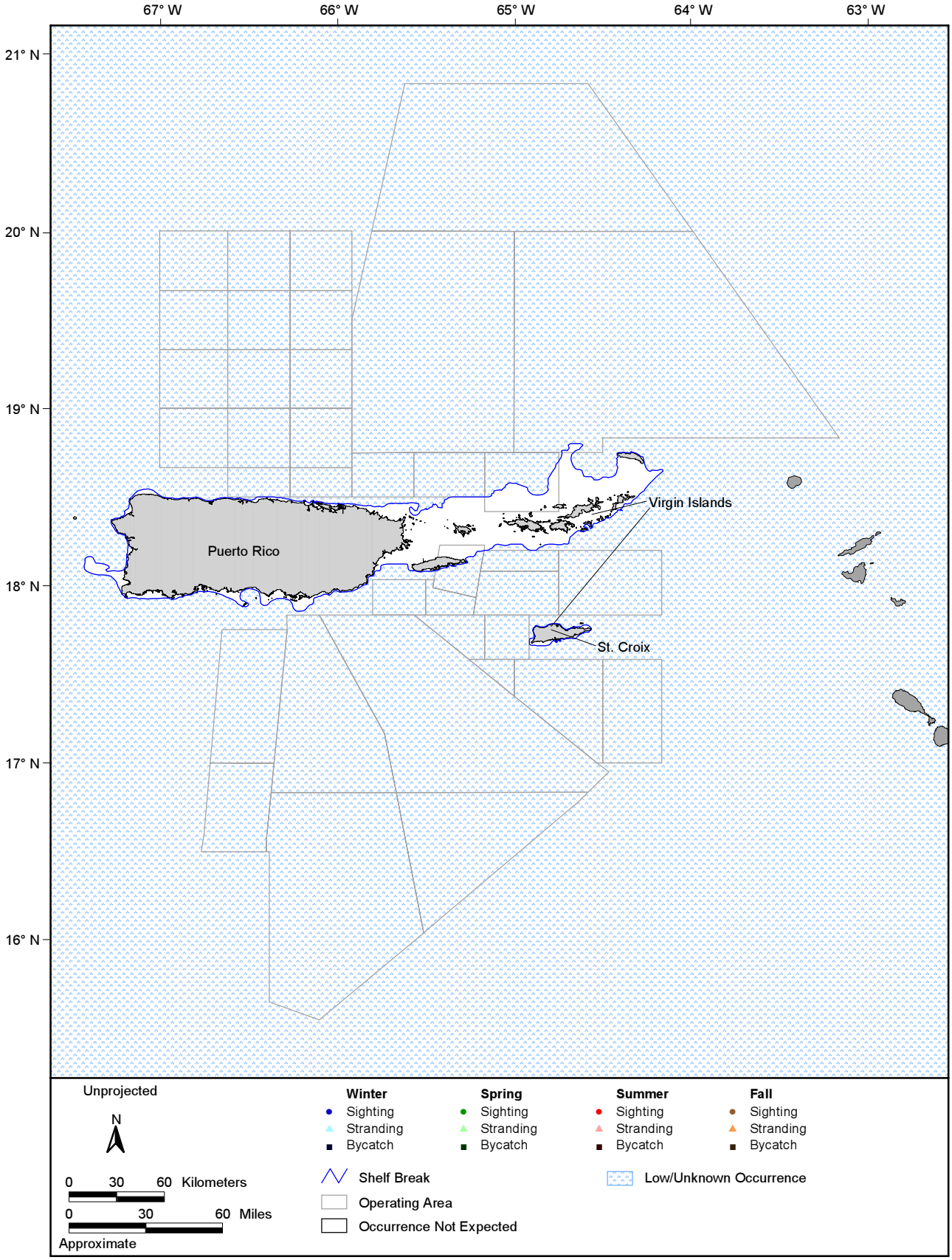


Figure B-19. Occurrence of the Clymene dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2..

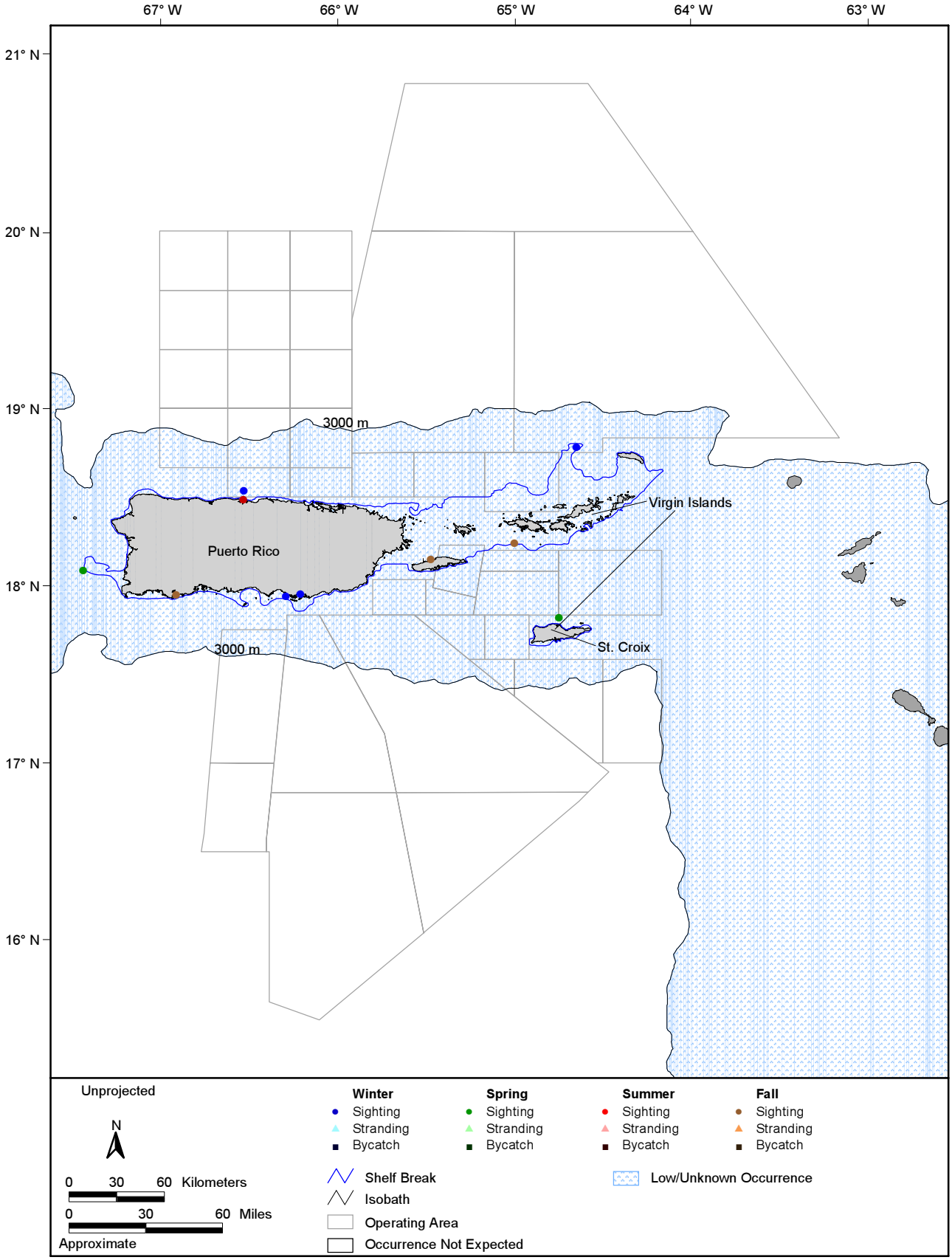


Figure B-20. Occurrence of common dolphins in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

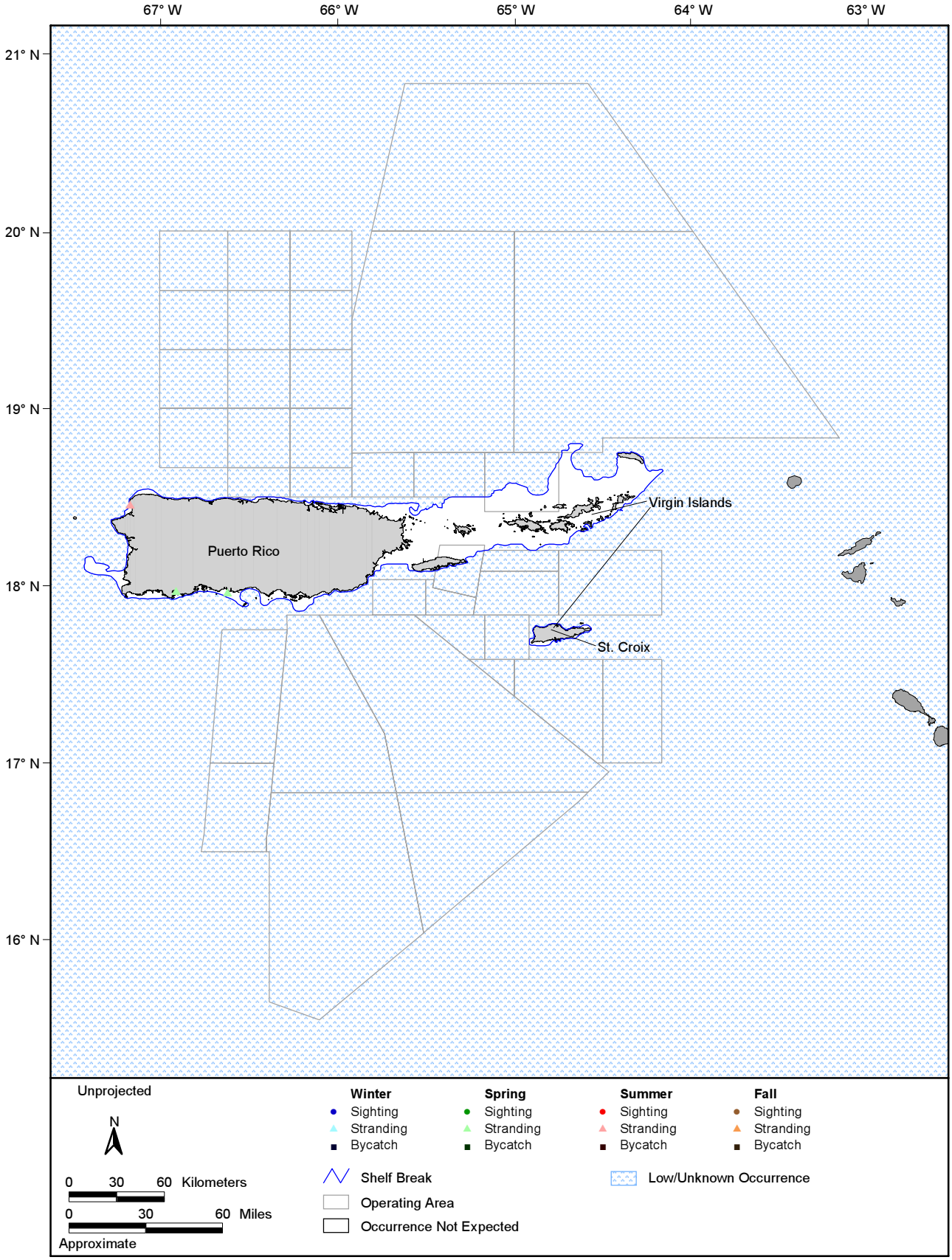


Figure B-21. Occurrence of the Fraser's dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

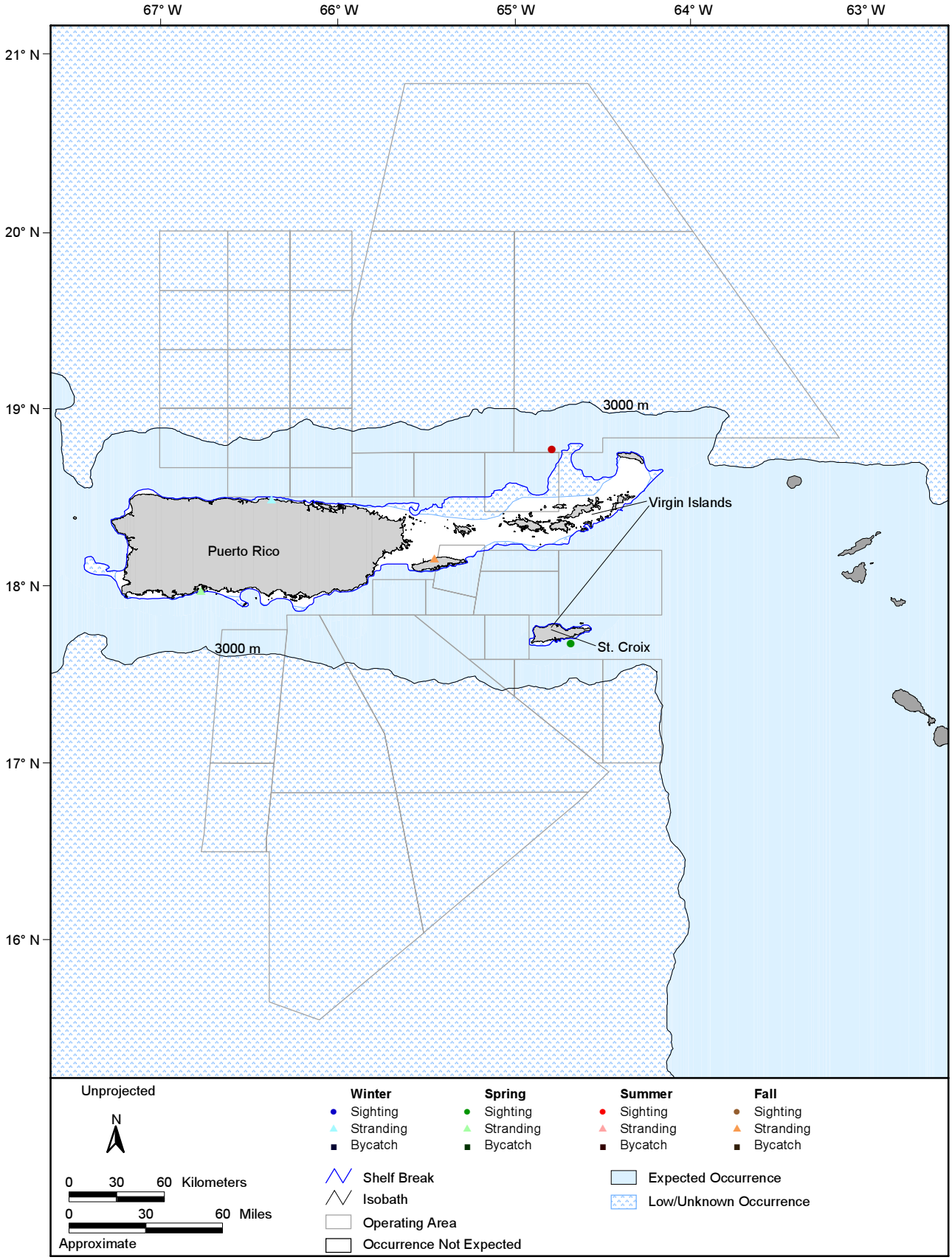


Figure B-22. Occurrence of the Risso's dolphin in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

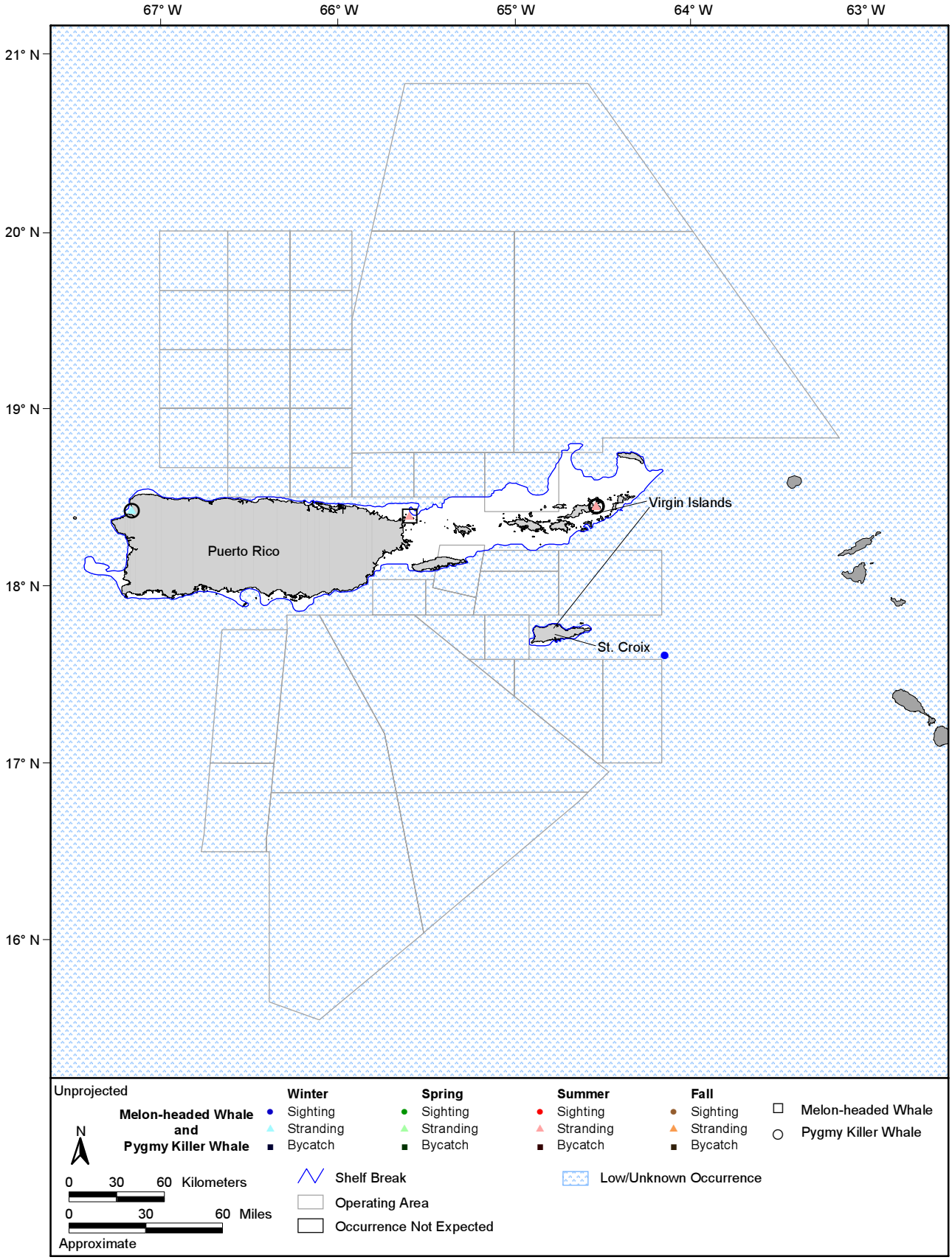


Figure B-23. Occurrence of the melon-headed whale and pygmy killer whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

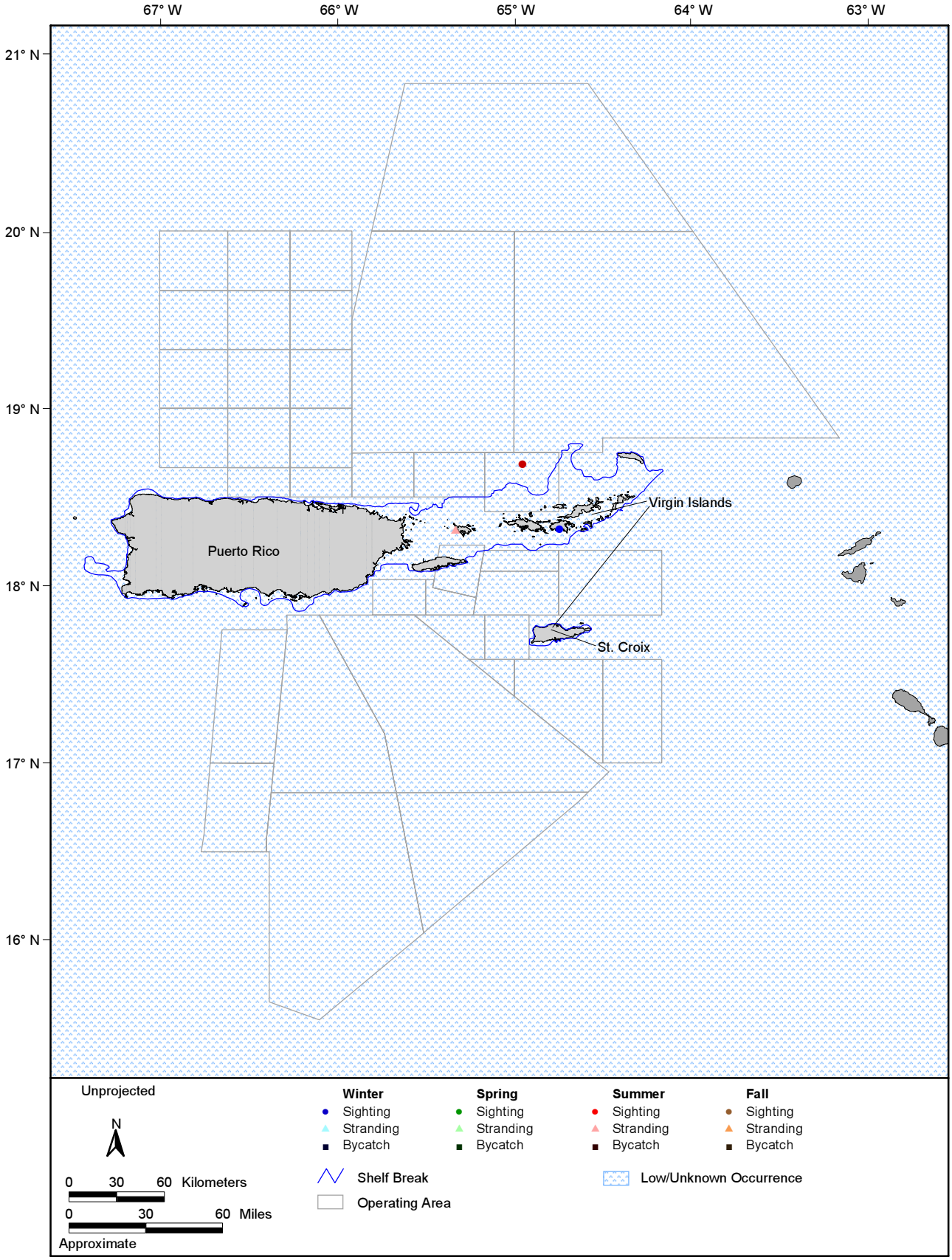


Figure B-24. Occurrence of the false killer whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

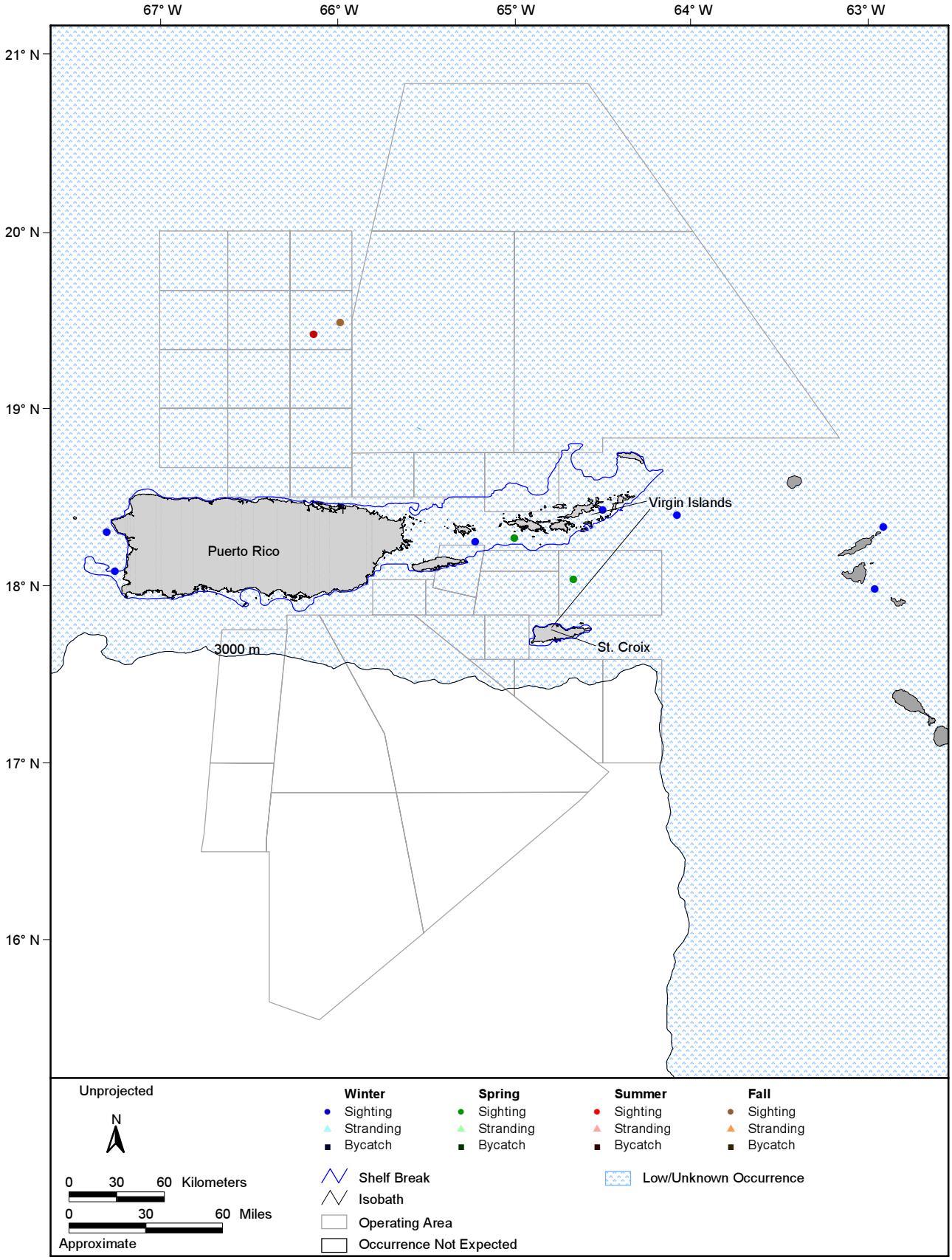


Figure B-25. Occurrence of the killer whale in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

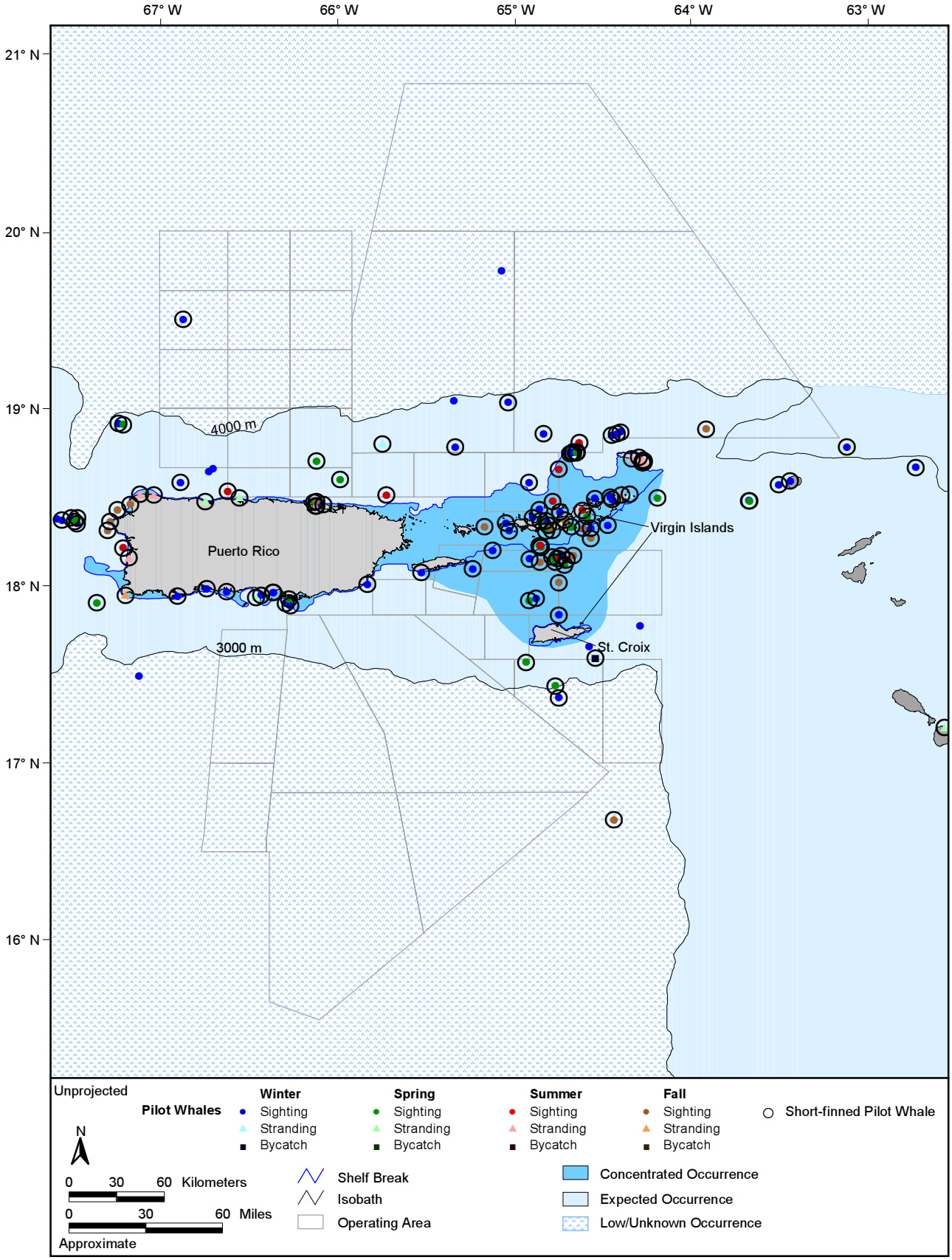


Figure B-26. Occurrence of pilot whales in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-2.

APPENDIX C: SEA TURTLES

Table

The seasonal distribution of sea turtle occurrence records in the PROA/St. Croix OPAREA by surface grid block C-1

Figure

Occurrence of all sea turtles in the PROA/St. Croix OPAREA and vicinity C-1
Occurrence of the leatherback sea turtle in PROA/St. Croix OPAREA and vicinity..... C-2
Occurrence of the green sea turtle in the PROA/St. Croix OPAREA and vicinity..... C-3
Occurrence of the hawksbill sea turtle in the PROA/ St. Croix OPAREA and vicinity..... C-4
Occurrence of the loggerhead sea turtle in the PROA/St. Croix OPAREA and vicinity C-5
Occurrence of the olive ridley sea turtle in the PROA/St. Croix OPAREA and vicinity C-6

Table C-1. The seasonal distribution of sea turtle occurrence records in the PROA/St. Croix OPAREA by surface grid block. Occurrence data are taken from available stranding and incidental fisheries bycatch records as well as aerial and shipboard sighting survey records. The total number of records is presented with the total number of individual animals in parentheses. The data presented are not reflective of survey effort.

GRID BLOCK	COMMON NAME OF SEA TURTLES			
	Green	Hawksbill	Leatherback	Unidentified
Winter				
6B		1 (1)		
W-428	32 (32)	7 (7)	2 (2)	19 (20)
Spring				
W-428	86 (876)	65 (66)	8 (8)	95 (100)
Summer				
3B				1(3)
4		1 (1)		
6B	1 (1)			
7		1(1)		
W-428	196 (220)	111 (1120)		190 (218)
Fall				
W-428	78 (80)	29 (33)	1(1)	233 (270)

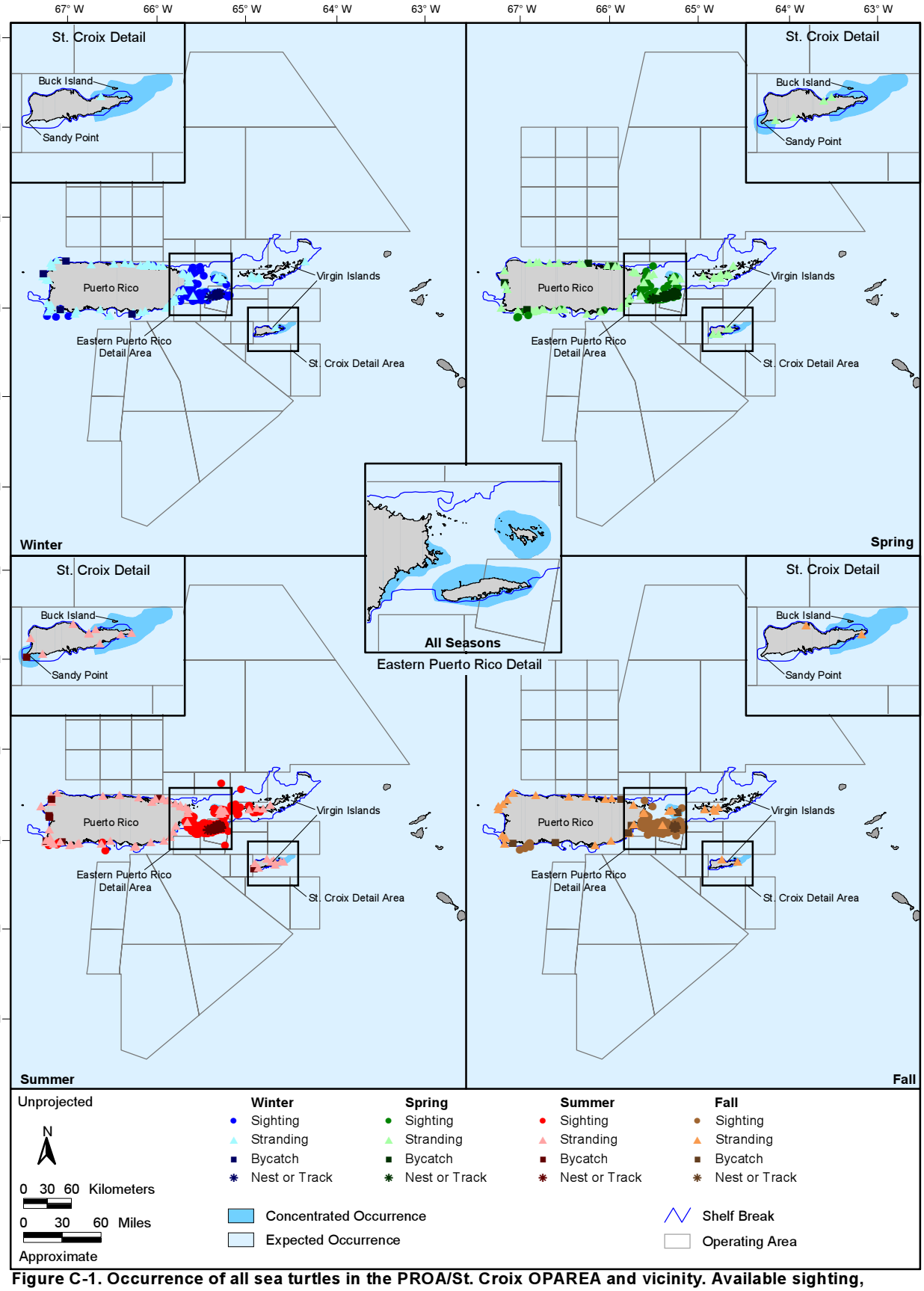


Figure C-1. Occurrence of all sea turtles in the PROA/St. Croix OPAREA and vicinity. Available sighting, stranding, incidental fisheries bycatch, nest, and track records are represented by season. Source data: refer to Table A-2.

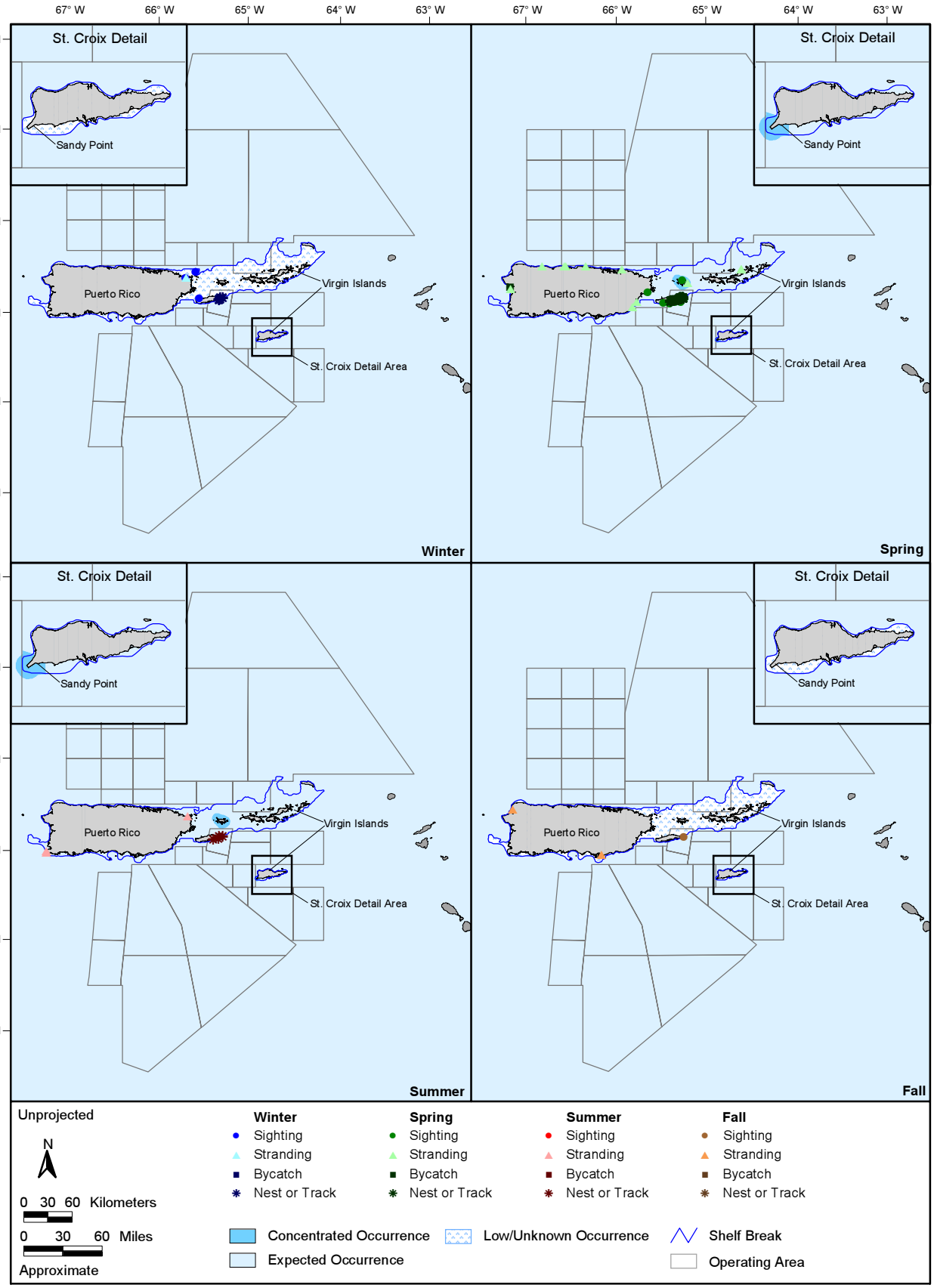


Figure C-2. Occurrence of the leatherback sea turtle in the PROA/St. Croix OPAREA and vicinity. Available sighting, stranding, incidental fisheries bycatch, nest, and track records are represented by season. Source data: refer to Table A-2.

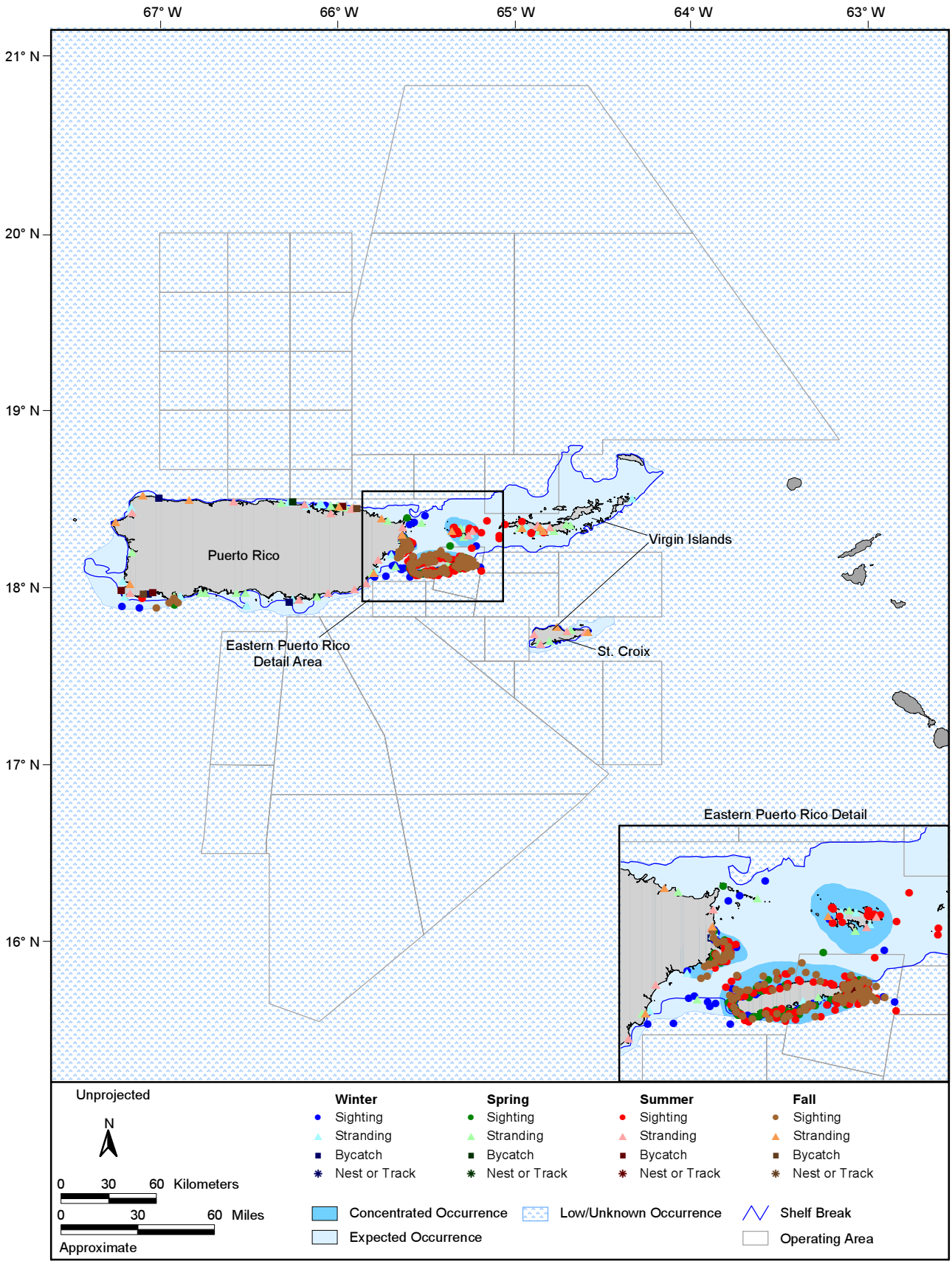


Figure C-3. Occurrence of the green sea turtle in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, incidental fisheries bycatch, nest, and track records are represented by season. Source data: refer to Table A-2.

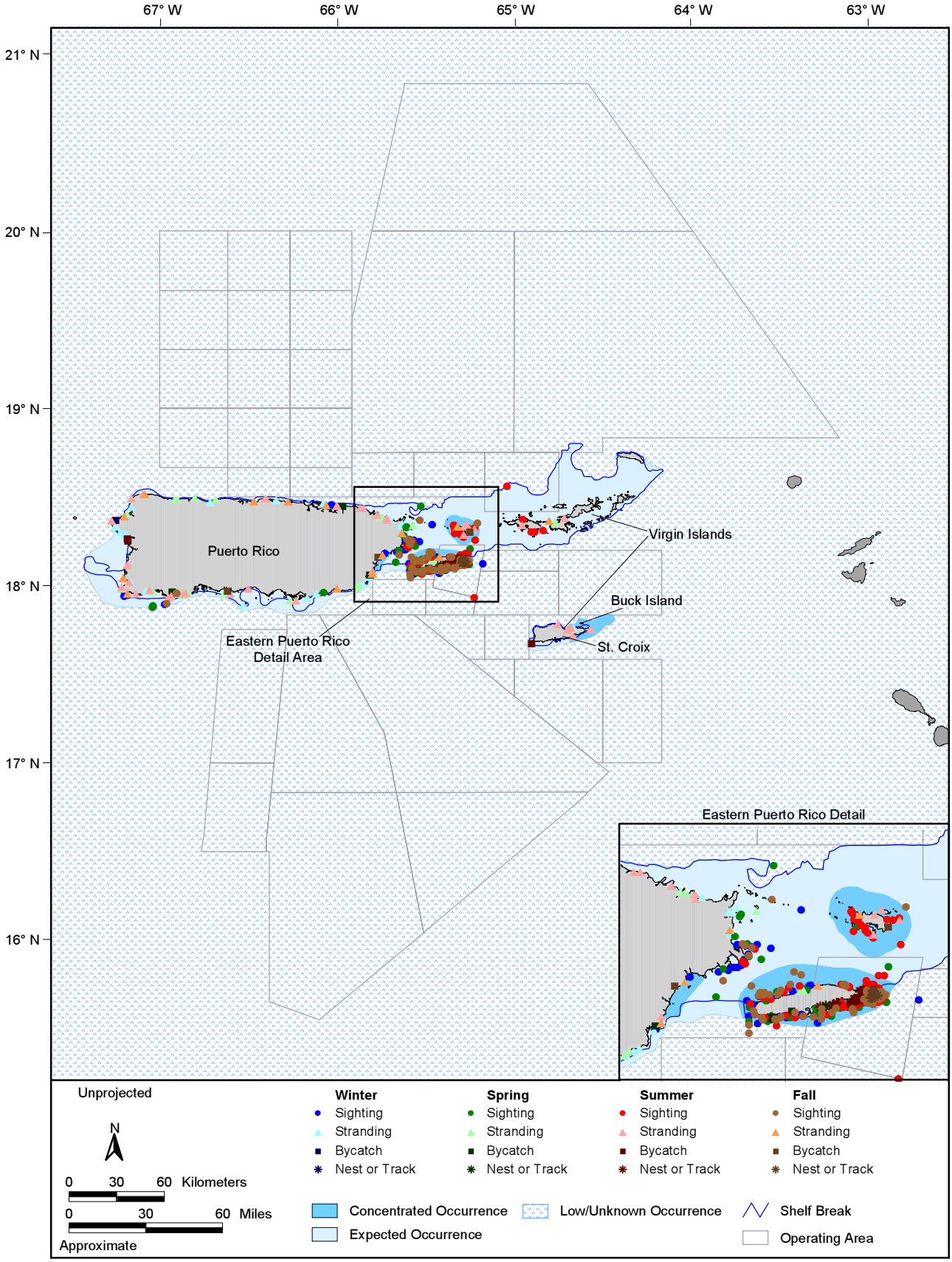


Figure C-4. Occurrence of the hawksbill sea turtle in the PROA/St. Croix OPAREA and vicinity. These occurrence patterns are applicable to all seasons. Available sighting, stranding, incidental fisheries bycatch, nest, and track records are represented by season. Source data: refer to Table A-2.

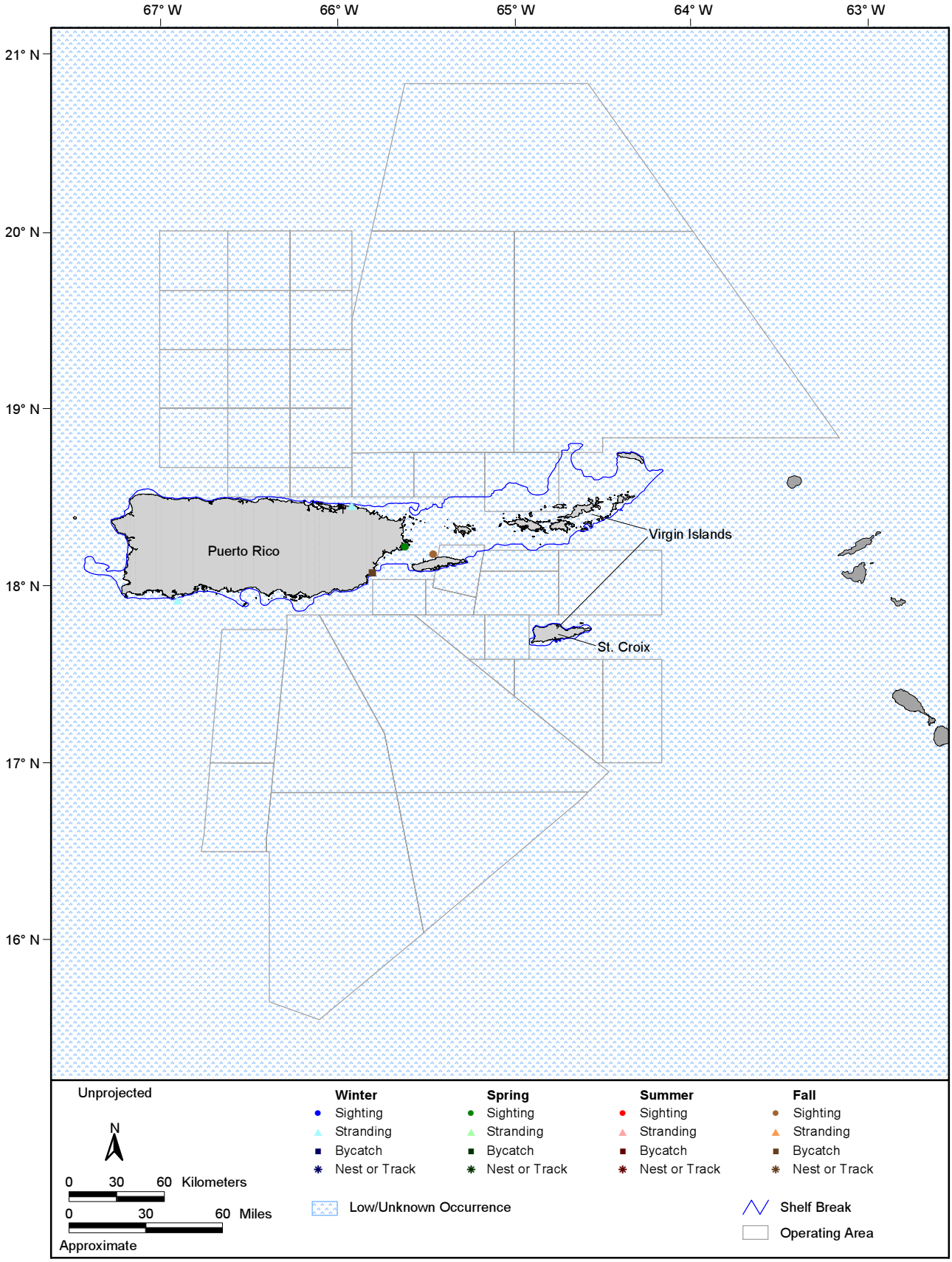


Figure C-5. Occurrence of the loggerhead sea turtle in the PROA/St. Croix OPAREA and vicinity. This occurrence pattern is applicable to all seasons. Available sighting, stranding, incidental fisheries bycatch, nest, and track records are represented by season. Source data: refer to Table A-2.

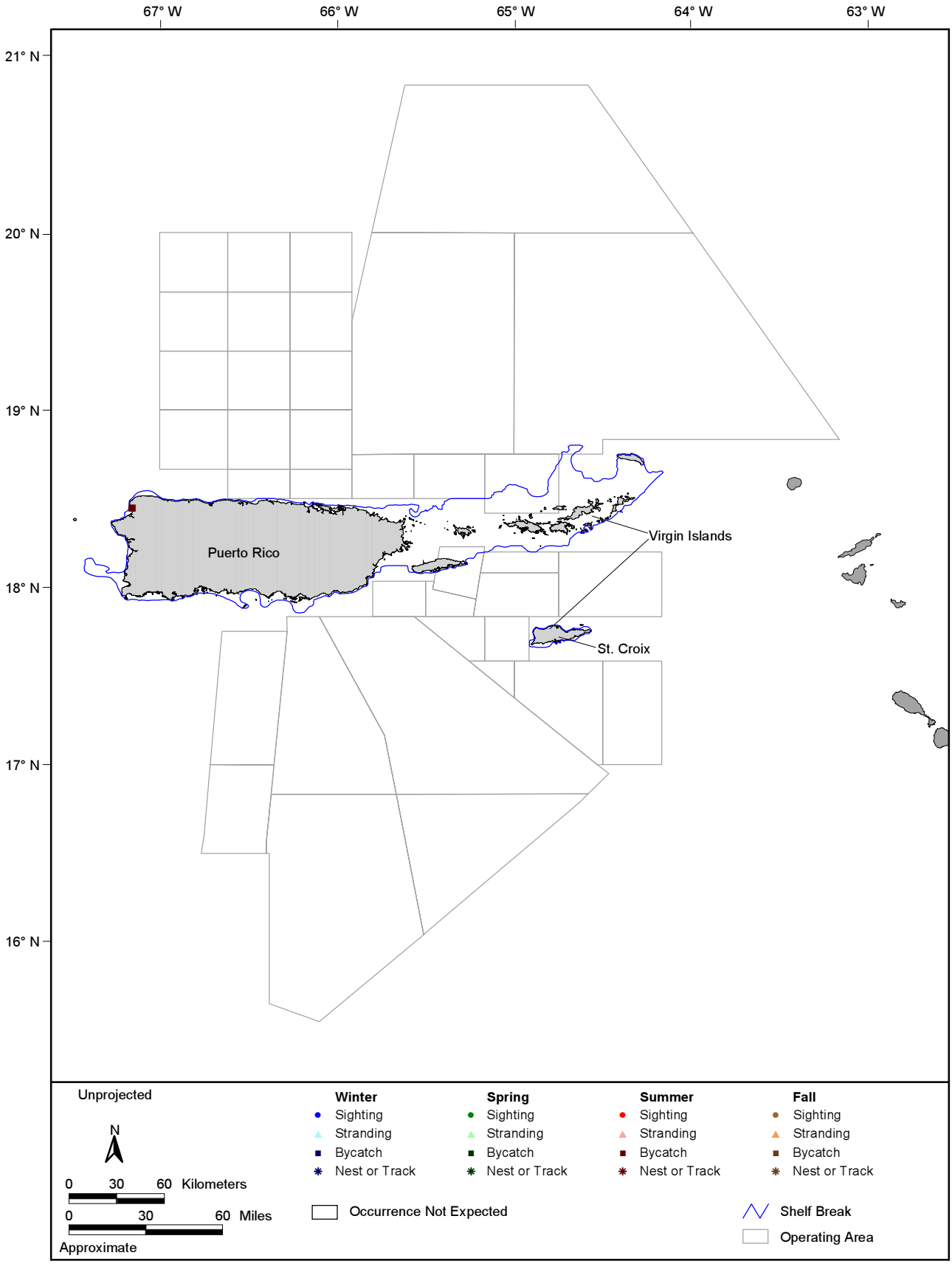


Figure C-6. Occurrence of the olive ridley sea turtle in the PROA/St. Croix OPAREA and vicinity. This occurrence pattern is applicable to all seasons. Available sighting, stranding, incidental fisheries bycatch, nest, and track records are represented by season. Source data: refer to Table A-2.

APPENDIX D: MYLARS

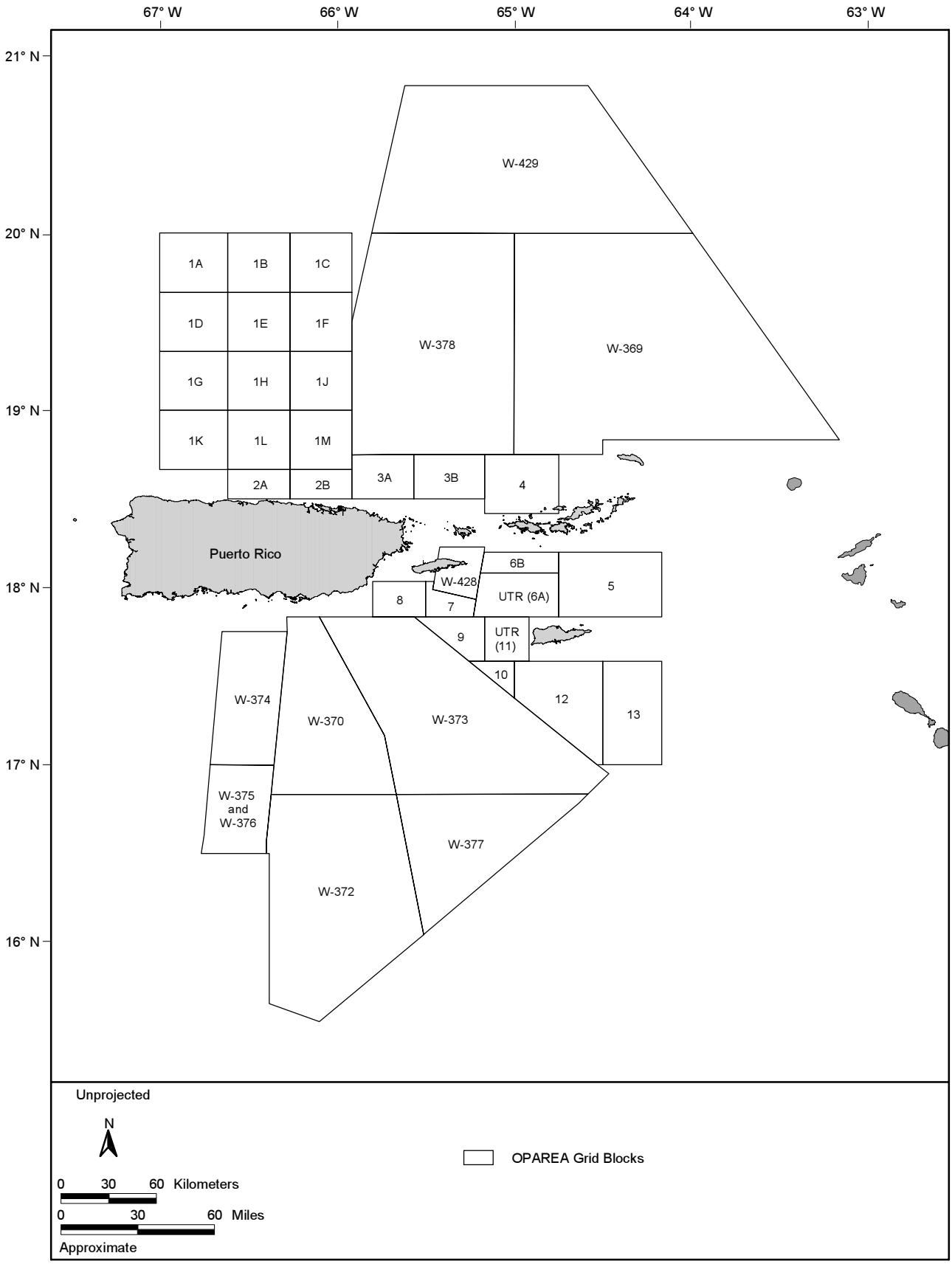
The PROA/St. Croix OPAREA is located in the northeastern Caribbean Sea and northwestern Atlantic Ocean and consists of the North and South Puerto Rico Operating Areas (PROAs) and the St. Croix Underwater Tracking Range (UTR) (full page)

The PROA/St. Croix OPAREA is located in the northeastern Caribbean Sea and northwestern Atlantic Ocean and consists of the North and South Puerto Rico Operating Areas (PROAs) and the St. Croix Underwater Tracking Range (UTR) (4 seasons)

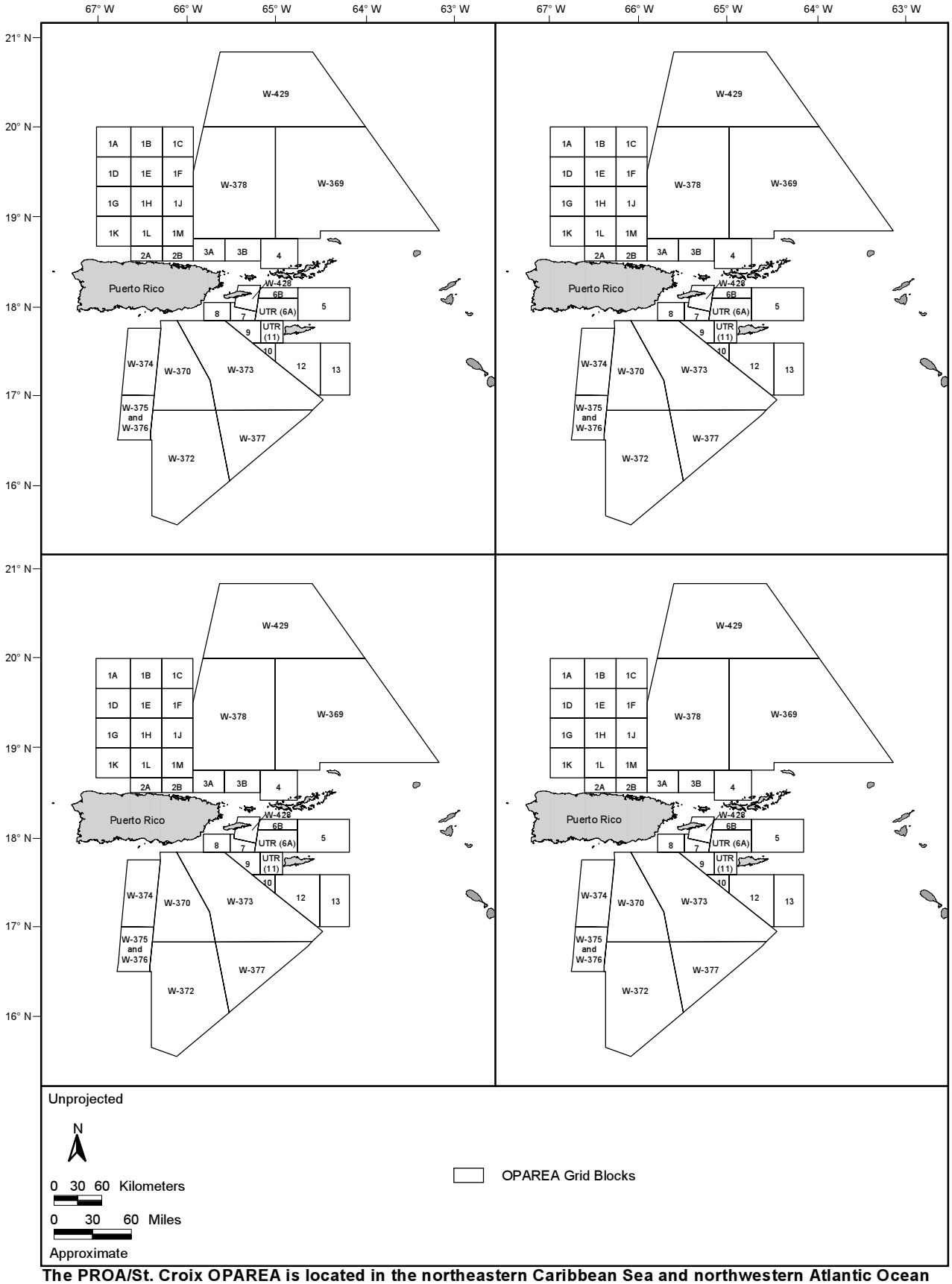
Detailed bathymetry of the PROA/St. Croix OPAREA and vicinity (full page)

Limited bathymetry (selected isobaths) of the PROA/St. Croix OPAREA and vicinity (full page)

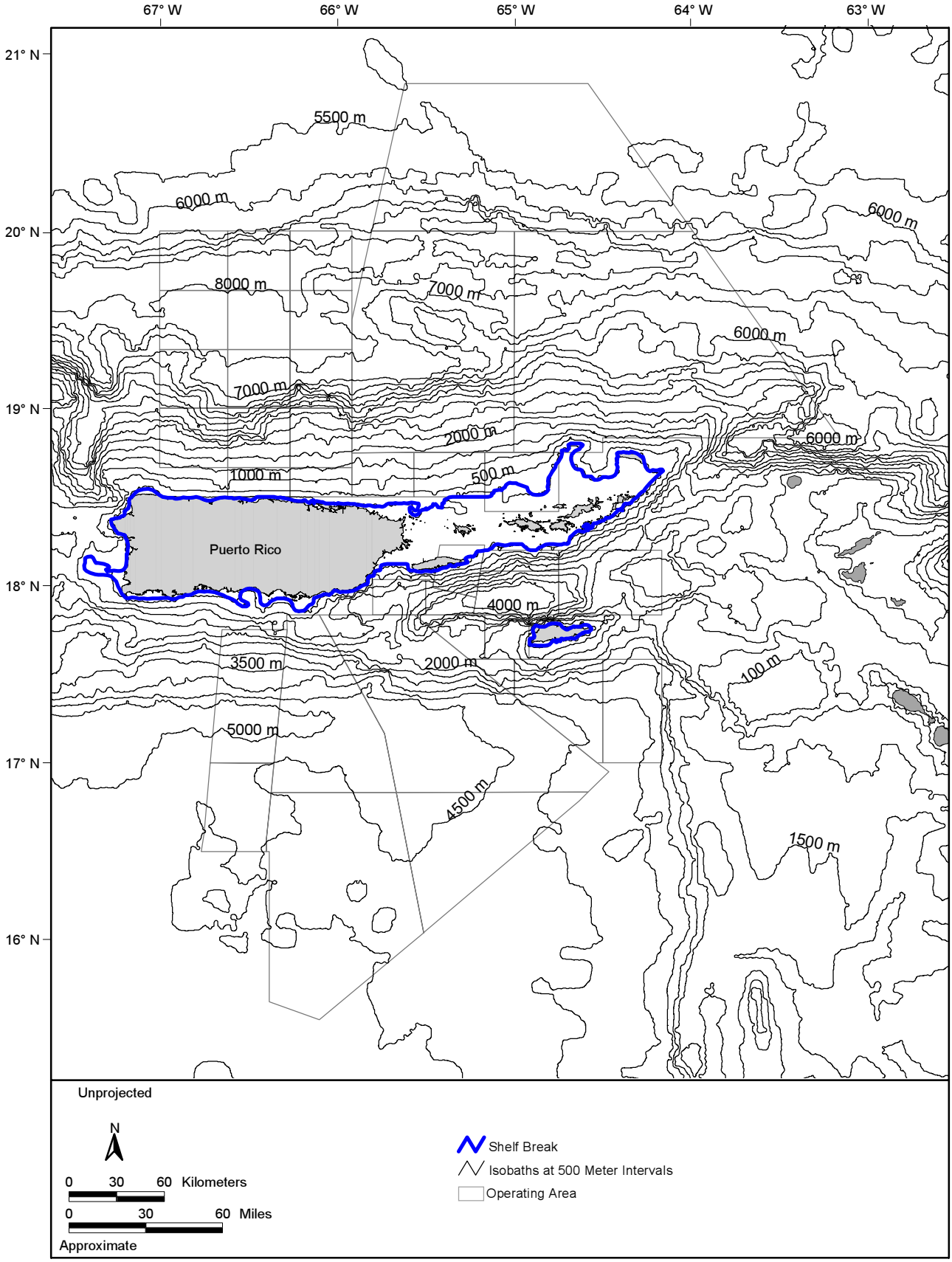
Limited bathymetry (selected isobaths) of the PROA/St. Croix OPAREA and vicinity (4 seasons)



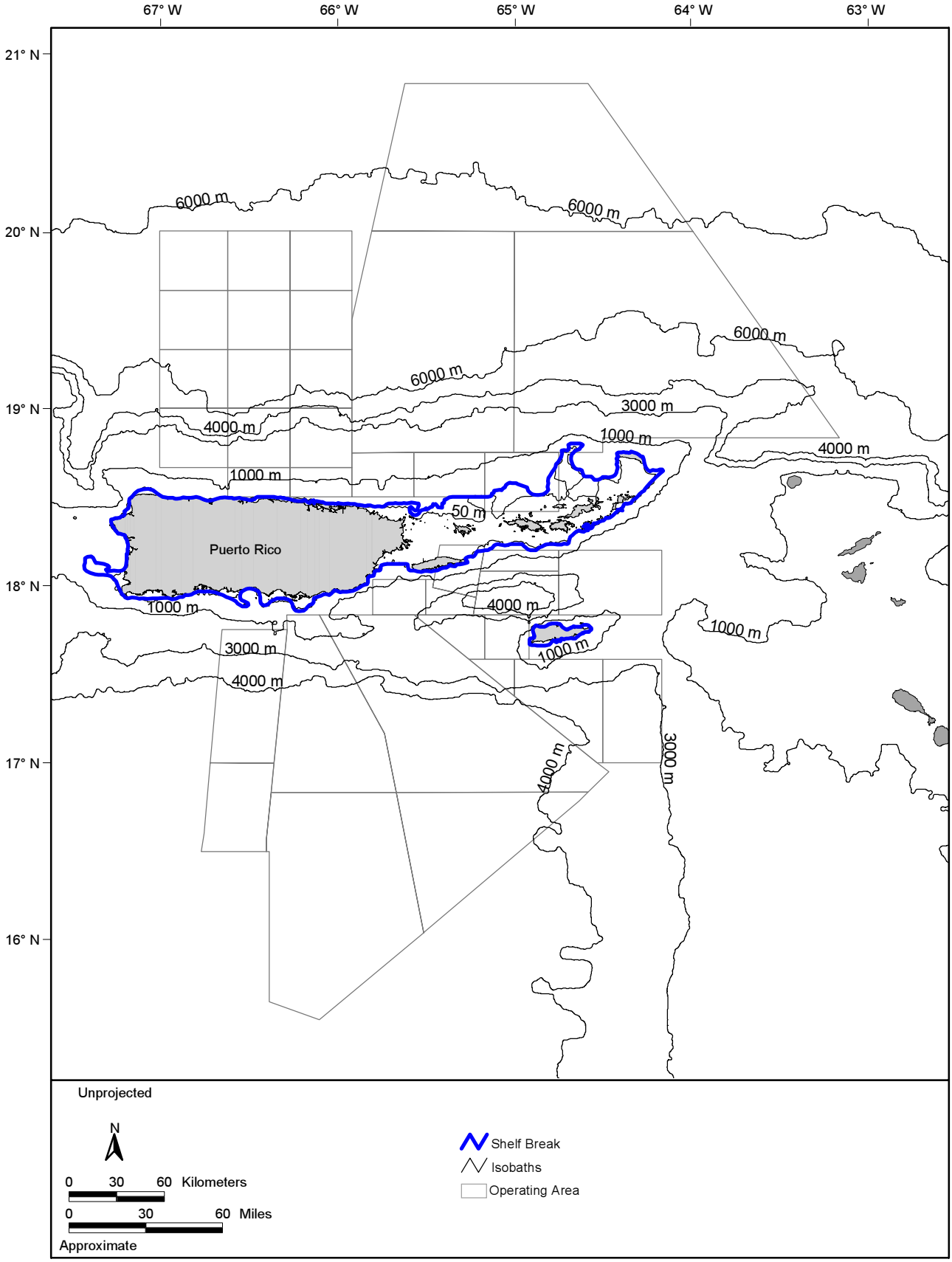
The PROA/St. Croix OPAREA is located in the northeastern Caribbean Sea and northwestern Atlantic Ocean and consists of the North and South Puerto Rico Operating Areas (PROAs) and the St. Croix Underwater Tracking Range (UTR).



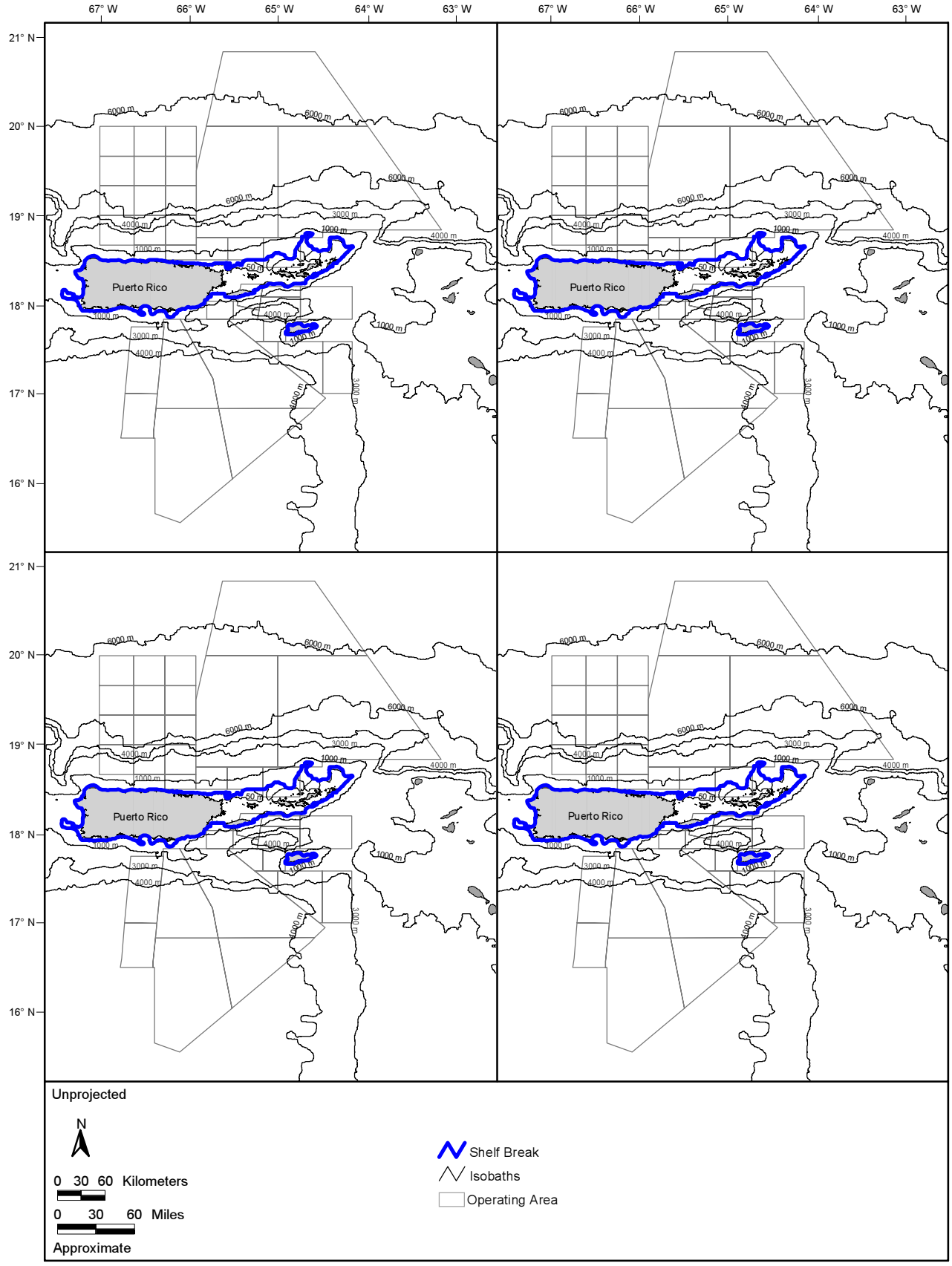
The PROA/St. Croix OPAREA is located in the northeastern Caribbean Sea and northwestern Atlantic Ocean and consists of the North and South Puerto Rico Operating Areas (PROAs) and the St. Croix Underwater Tracking Range (UTR).



Detailed bathymetry of the PROA/St. Croix OPAREA and vicinity.



Limited bathymetry (selected isobaths) of the PROA/St. Croix and vicinity.



Limited bathymetry (selected isobaths) of the PROA/St. Croix and vicinity.